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AIEE WINTER MEETING, NEW YORK, N. Y., JANUARY 27–31, 1947

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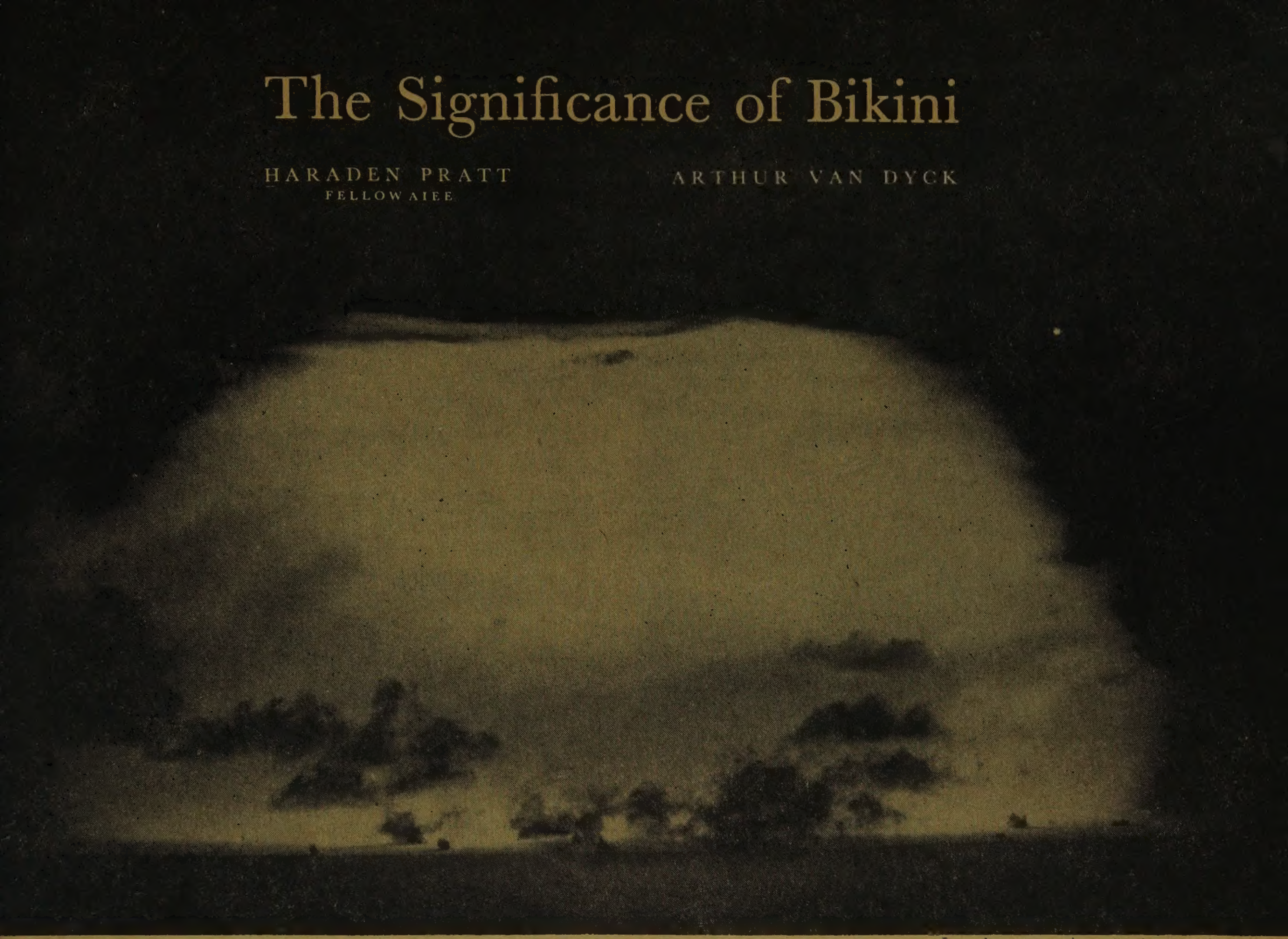
The Significance of Bikini

HARADEN PRATT
FELLOW AIEE

ARTHUR VAN DYCK



Incandescent gases immediately after blast

The outward physical manifestations of heat, power, and radioactivity unleashed do not represent the true significance of the atomic bomb tests at Bikini Atoll. Since the short period after Hiroshima and Nagasaki when an earnest and humble effort was made to find the right answer to the control of nuclear fission a generally complacent attitude has developed. That the peoples and rulers of the world need to be educated to the revolutionary conditions related to the atomic bomb there can be no doubt and avoiding the facts that are before us will not solve the problem.

THE observers of Operation Crossroads, code name for the atomic bomb tests held at Bikini Atoll, Marshall Islands, were accommodated on ships of the general communications type. Designed to carry large military, naval, and air staffs in amphibious operations, they provided ideal quarters for this purpose. The observers were of several kinds: scientific men from the United States and the United Nations, United States congressional representatives, officers of the United States War and Navy Departments, and representatives of the press. In spite of the size and complexity of Operation Crossroads, it was executed in most efficient fashion throughout and the excellent handling of observers was but one example of the general effectiveness of the organization, which was under the able command of Vice-Admiral Blandy.

The *USS Panamint* to which we were assigned, arrived at Bikini Lagoon on the morning of June 29 and immediately steamed to an anchorage a short distance from Bikini Island by moving very slowly through the entire target array of some 72 ships. The sight was impressive in all respects. A mighty fleet was anchored row upon row on the azure waters of an immense tropical lagoon fringed with palm covered islands, waiting for the awesome test scheduled only two days away. Battleships, cruisers, carriers, destroyers, submarines, transports, and ships of other smaller types—even to a concrete

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Essential substance of a paper presented by Haraden Pratt at a joint meeting of the AIEE New York (N. Y.) Section, the New York section of the Institute of Radio Engineers, and the Radio Club of America.

Haraden Pratt is vice-president and chief engineer of Mackay Radio and Telegraph Company, Inc., New York, N. Y. **Arthur Van Dyck** is assistant to the vice-president in charge of the Radio Corporation of America laboratories, New York, N. Y. Mr. Pratt and Mr. Van Dyck were official United States scientific observers at Operation Crossroads.

Illustrations from Joint Army-Navy Task Force One photographs.

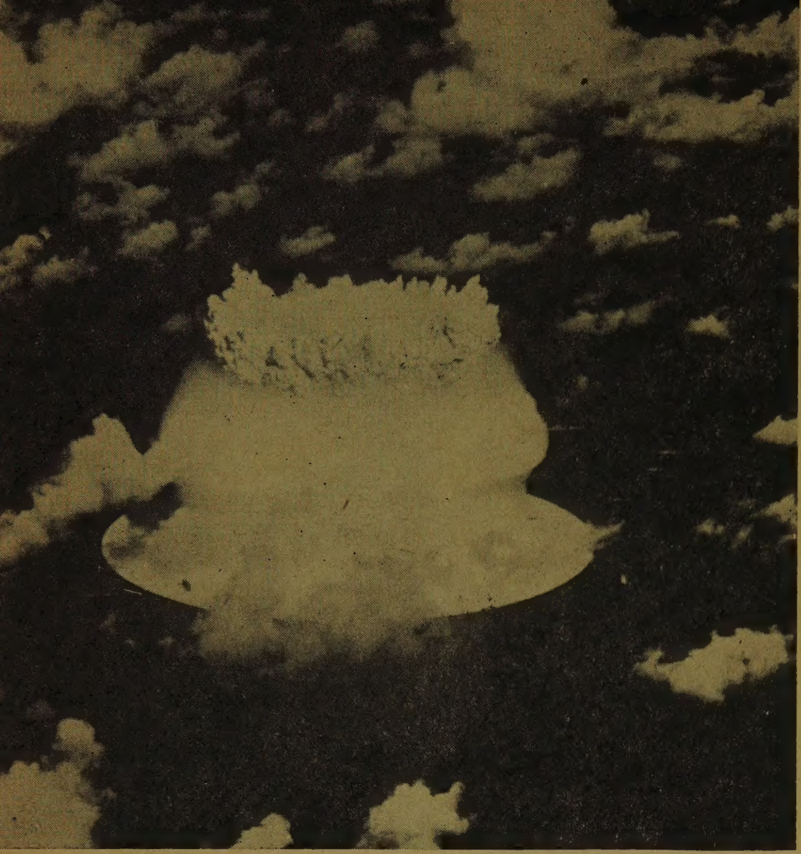


Figure 1. **Aerial view of gas cloud shortly after incandescence faded; note anchored ships and circular base of cloud caused by air shock wave**

floating drydock—were grouped variously around the target's bull's eye to which the observers' glance continually reverted, namely, the majestic battleship *Nevada*, conspicuous in bright orange paint with white turret tops and guns, the better to guide the bombardier on the fateful day.

It was obvious that these ships had been prepared for this special event as they were disposed in a pattern intended to reveal maximum information on damage at all distances. Their decks were fitted with all kinds of equipment and materials of war to be subjected to the explosion. Each ship had graduated scales painted on bow and stern so that settlement could be noted from time to time through observation from aircraft. Even the islands bore evidence of the vast preparation that preceded our visit, as several steel towers to accommodate cameras and other instruments were easily visible.

That afternoon we visited the *Nevada*, the Japanese battleship *Nagato*, and the carrier *Independence*, where we saw the large number of test specimens mounted on their decks. These included samples of clothing, food, armor plate, airport fuel trucks, medical supplies, airplanes, and hundreds of other items of military weapons and supplies. The *Nagato*, commissioned about 1921, was of particular interest with her war wounds of the two direct hits from aerial bombs, including the skip bomb that went right through the ship via Admiral Yamamoto's quarters.

Long studies of Bikini July weather indicated that perhaps as many as 20 days could elapse before a suitable one for the drop would arrive. Besides adequate visibility it was required that the wind blow in the same direction from sea level to 20,000 feet so that radioactive products of the atomic fission would move away from all observers and not endanger them in the event of rain. However, on June 30 such weather was predicted for July 1, and the fleet of some 140 attending vessels steamed out of the lagoon maneuvering during the night to be at their assigned locations for Test Able at 8:30 the next morning.

TEST ABLE

We on the *Panamint* saw the blast from the bridge deck through very dark special goggles at a point about 20 miles from the *Nevada*. Not being able at this distance to see any of the target fleet, many of us were not looking directly at the correct spot and so missed the initial point of flash. By the time our eyes had moved the burst appeared to be a disk somewhat larger than the sun and considerably brighter, a conclusion made possible by being able to glance at the sun several times before the ship's public-address system announced "bomb away."

The disk of intense light was blotted out immediately by the instantaneously formed luminous dome or hemisphere of incandescent gases which rested on the water covering much of the target area. Quick loss of luminosity occurred, and with bare eyes we viewed the majestic column of atomic cloud with its mushroom top rise and shoot some several thousand feet skyward in a matter of seconds. We estimated that this structure rose to a total of some 38,000 feet, displaying from the start interesting shades of pinkish colors against a fleecy white. The yellowish aspect of previous atomic explosions, ascribed to dirt and debris, was, of course, absent at Bikini.

By 11 that morning, we had moved up to the reef and examined the target fleet through binoculars seeing at the same time yellow-colored drone boats darting about picking up water samples to test for radioactivity. These boats were remotely controlled from a distant destroyer with air units observing and directing. Test results were favorable for certain parts of the lagoon and our ships took anchorage there soon after noon. Here we were able to survey the fleet clearly and note the many wrecked superstructures. The outstanding spectacles were the Japanese cruiser *Sakawa* with a list, a completely wrecked top side structure, and down at the stern, and the carrier *Independence* with bad fires which culminated toward evening in spectacular explosions leaving the ship a shambles. The *Sakawa* turned turtle and sank the next morning.

Interesting and spectacular as all these events were, the full realization of the enormity of what had taken place unfolded rather slowly during succeeding days as we visited and examined ship after ship. Lessened radioactivity enabled ships to be boarded 48 hours after the burst. Within 3/4-mile radius, exposed wood was scorched black, crates and boxes were burned, and the *Nevada's* after deck, hit by the blast at an angle of about 25 degrees, was crushed down and blackened. Her funnels were pushed into her superstructure and the airplane crane on her stern bent double. It should be explained that, after striking bull's eyes on many practice runs, the bombing plane had the hard luck on the real drop of missing the *Nevada* by some hundreds of feet, a sore disappointment to the Army Air Forces.

Conditions were the same on the *Arkansas*, and worse on the *Pensacola* which was within a 1/2-mile radius. All these vessels' decks and superstructures were a mass of wreckage, with bent bulkheads, twisted railings, smashed doors, stacks down, antenna gear deformed or broken—peeling paint resulting from the heat wave, and the damaged or burned-out specimens placed on their decks. The blast wave even penetrated below, wrecking furnishings and doing other damage in spots here and there. Many vital items were damaged seriously, such as bulkhead-mounted motor-control cabinets, the switches and other parts of which were broken loose and completely inoperative. Broken castings in quantity taught that naval ships of the future must avoid the use of metal fabricated in brittle forms.

It was unfortunate that our public was misled during the weeks preceding the tests by statements appearing in the press forecasting dire results and the possible unleashing of forces of nature such as earthquakes, tidal waves, and volcanic eruptions. It must be remembered that the effects of explosions diminish very rapidly with distance, and while the atomic holocaust sank and wrecked vessels up to a half mile from its center, damage to ships beyond a mile was relatively light. Heat, blast, and wave action at Bikini Island three miles away left almost no visible traces. Even direct blast and heat damage from huge volcanic explosions such as Krakatoa and Katmai extended over only small areas. Certain excited spectators, therefore, had no logical basis for reporting disappointment because Bikini trees were not uprooted or because the blast at 20 miles did not blow them off their feet.

It must be remembered that, while five ships were sunk in the air test and about nine sunk plus two beached in the underwater test, conclusions as to the power of atomic bombs should not be based on the number of ships sunk. Obviously, if the whole fleet had been bunched closely most would have been sunk, whereas if dispersed widely not more than one such casualty would have occurred.

"POISON BOMB"

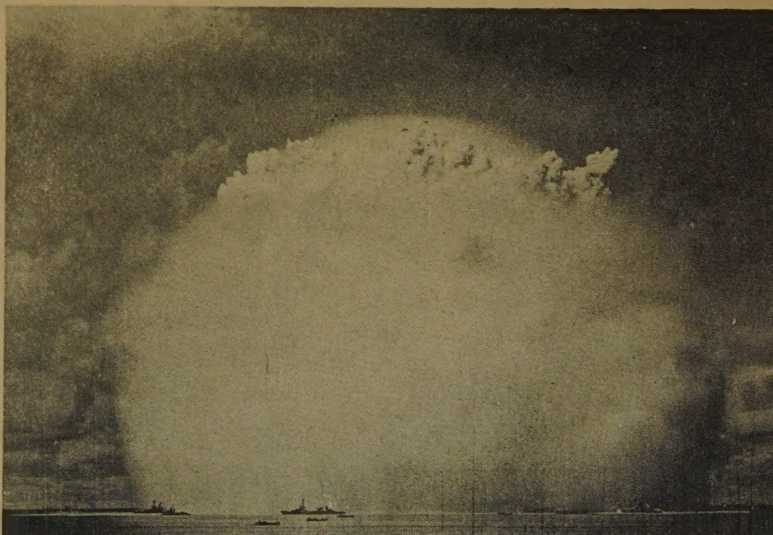
However, all these arresting phenomena, significant in their seriousness as they are, represent only the effect of heat and explosive action arising from the concentration of stupendous power at a single point. The effects of radioactive radiations, primarily neutrons and gamma rays, constitute the feature which justifies the appellation of "poison bomb" as conveying the real meaning of this colossal development. Even though radiation diminished so fast after the first test as to enable ships to be visited safely a few hours later, it is doubtful whether but a few could have survived aboard if the ships had been manned when the bomb was dropped, even though the bulk of the crews might have lived long enough to render ships operative and resist post-explosion attack.

Any doubts as to the sweeping nature of the poison effect which may have existed were removed after the second atomic bomb was exploded below the surface of Bikini Lagoon. Millions of tons of sea water, hurled skyward over one mile in a column almost a half mile in diameter were heavily contaminated with the fission products estimated as equivalent to hundreds of tons of radium. In the first test these products distributed in the atmosphere and were dispersed by the winds. This death-laden water in the second test fell directly on all ships in the lagoon and engulfed some in waves 70 to 100 feet high, resulting in radioactive products being washed down ventilators, pipes, funnels, and scuppers, in saturation of all topside hamper, and in penetration to hidden places such as circulating systems, pumps, and evaporators.

Even ships not in the target fleet became dangerously contaminated by entering affected lagoon areas afterwards. Many of the surviving vessels are still uninhabitable and others present vexatious problems of reconditioning because of gamma rays coming from materials lodged in the scale and incrustations inside sea-water piping.

Much has been said as to whether the tests were necessary and their cost justified, even though the cost was less than the value of a single modern battleship. Our considered opinion is that the tests were indispensable. Aside from arguments that scientists fairly well might predict results, and apart from the tremendous value of the precise technical information acquired, the mere holding of the operation under controlled conditions with many observers from all walks of life was of incalculable value to all mankind because

Figure 2. Gas cloud shortly after incandescence faded



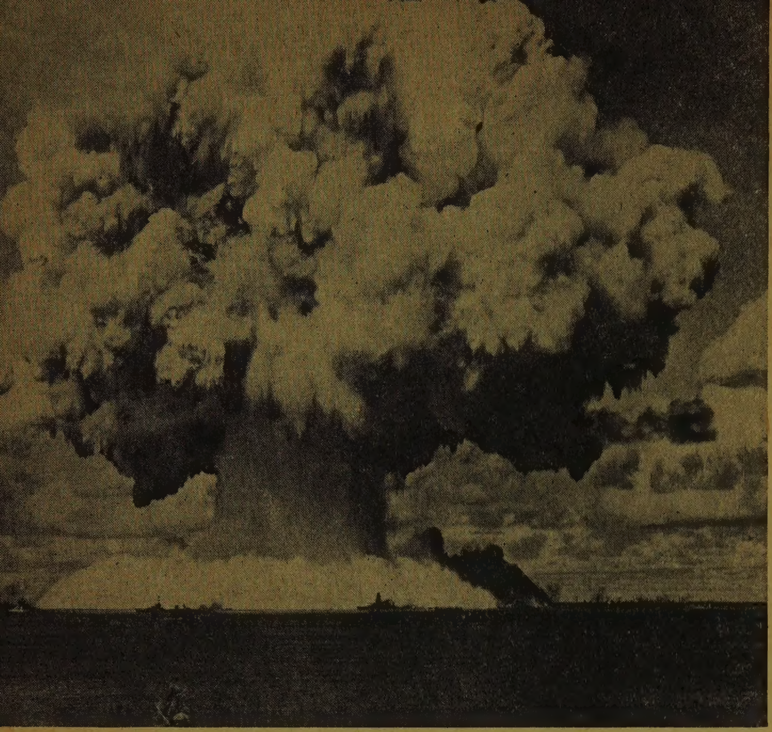


Figure 3. Water column from underwater blast collapsing

the impact of the atomic bomb reaches human beings everywhere, and there is no substitute for actual results to drive home the facts indisputably.

SIGNIFICANCE OF TESTS

The significance of the Bikini tests is clear and powerful. Nevertheless, it has been the universal experience of the United States observers, on returning from Bikini, that people with whom they have discussed the matter have been uncertain as to the significance of the tests and of the atomic bomb generally. We even have found many people who are unwilling to talk or think about the subject, saying that it is just too horrible to contemplate. We would like to convince such people, and all people, that the atomic bomb not only is horrible, but that it is so terrible that something must be done about it. That something is not to hide our heads in the sand—it is that we must insure ourselves against its use. And that means we must somehow prevent all war in the future.

The facts are very clear, and the best presentation may be merely to list them in simple language.

An atomic bomb of the present type exploding in the air, destroys everything within about a quarter mile, does very heavy damage to a half mile, and heavy damage to a mile. Beyond a mile, the degree of damage depends upon the character of structures. Windows and light structures will be shattered at several miles.

An atomic bomb of the present type kills practically all the human beings within a quarter mile, a very high percentage of those within a half mile, and a great many of those within a mile or more.

The present-type bomb, bursting in the air over New York, N. Y., would blow out every window within one or two miles and would knock off most of the roof structures and brick and stone facings of buildings, particularly skyscrapers. Casualties from glass and falling debris would be high. Fires from short-circuits, broken gas mains, and other causes would be numbered in hundreds.

The present-type bomb bursting under the water around New York would destroy subways, and would render uninhabitable for months an area of at least ten square miles. Each seaport city of a country would be similarly exposed.

The atomic bomb is not the only new weapon of vastly increased destructiveness. The guided missile, like the German *V*-1 or *V*-2, is another. The power and destructiveness of weapons has been increasing rapidly for the last 100 years. World War I saw the first wide use of high explosives. World War II achieved vast destruction. Most people of the United States do not realize this. The people of London, Coventry, Rotterdam, Warsaw, Stalingrad, Berlin, Tokyo, and Pearl Harbor *do* realize it.

World War II dislocated civilization, and might have wrecked it almost completely through destruction of so much of the economic structure of the world. Actually perhaps it has, because we do not see a definite path to peacetime normalcy, particularly in Europe and Asia.

A third world war will be vastly more destructive of both economic structures and of human beings. Because World War II was almost enough to destroy civilization, a vastly worse World War III is certain to do so.

NO ATOMIC BOMB DEFENSE

There is no defense against the atomic bomb or against the guided missile, or of course, against a combination of the two. Defense never has been perfect against any weapon. Against the atomic bomb, unless the defense is perfect, it is no defense. Not one German *V*-2 missile was shot down of the many that approached London. If two or three of them had had atomic bombs in them, London would have become an empty shell.

We now have reached that advanced state of civilization wherein we have made it possible for a few uncontrolled members of our society to destroy or to subjugate the rest of us before we can do anything about it. The fact is that material development has reached a dangerous level. We have been settling arguments by force from the beginning of man on earth, but usually the side of moral right has been able to marshal enough might to prevail sooner or later.

Now we have a new situation, and there is no protection left in material things. Forts and trenches have failed, the Maginot Line failed, the English Channel failed, the oceans have failed. New weapons pierce even the stratosphere.

All this has been said before. In fact, it has been said so many times that the thought has become familiar and has lost its true meaning to many people. This complacency is dangerous. These facts mean that a revolution in human affairs has occurred. Hereafter civilization must struggle not to advance, but actually to survive. These are not mere words, they are elementary truths. All this should be obvious to everyone, and particularly to those men charged with the responsibility of government. There was a time, shortly after Hiroshima and Nagasaki, when leaders were alarmed and earnestly and humbly sought for the right answer. But they quickly recovered from that lapse from diplomatic protocol, and today we see national and international leaders operating in the old-fashioned way, ignoring the new facts of life.

It is necessary now to avoid not only war, but the threat of war and the necessity of preparations for defense in war. Even these latter, without war itself, would largely destroy our free civilization because of the continuous state of "war of nerves" existence, and the vast changes required in our economic life. Even a moderate degree of preparation for an atomic war would require huge changes in the American way of life.

In past centuries, despots often have declared sudden war on unwary and unprepared peoples. In our time, we have seen Germany do it twice and Japan once. They did not win—and only because their tools were not equal to the job of subduing us before we were able, under the spur of our peril and our righteous wrath, to prepare defensive means and offensive retaliation was this true. It took all the resources of Japan to carry out one Pearl Harbor at a time. Now it is different. Now despotic rulers, minded as were those of Germany and Japan, can overnight deal such crushing blows to another nation or nations, that recovery and retaliation will be impossible.

Therefore, it is obvious that the only safety is in means which will make it impossible for any nation to attack another.

CONTROL ESSENTIAL

The only possible safe policy for the future must be one which rests on the law and the conscience of man. Nations must be controlled, as we now control states, counties, cities, and individuals.

The people of *no* country want war. Then how do wars come about? In our time, as almost always in the past, they developed from the ambitions of rulers of countries. One of the greatest virtues of an effective democracy is that the actions of its rulers reflect most nearly the wishes of its people. If all rulers' tenure of office were limited to a few years, perhaps the urge to war would be reduced to the vanishing point.

The outstanding need of the moment is to explain these revolutionary facts and conditions to all peoples and rulers of the world. It will take skill and patience to give the required teaching, particularly in countries where the facilities for information dissemination are not good. It will be difficult, because so many for so long have paid so little attention to moral law and conduct among peoples. But it must be done, if life in the future is to be worthwhile, because there is no other way to avoid cataclysmic horror.

We must have world law and order. That is the simple significance of nuclear fission—and of Bikini.

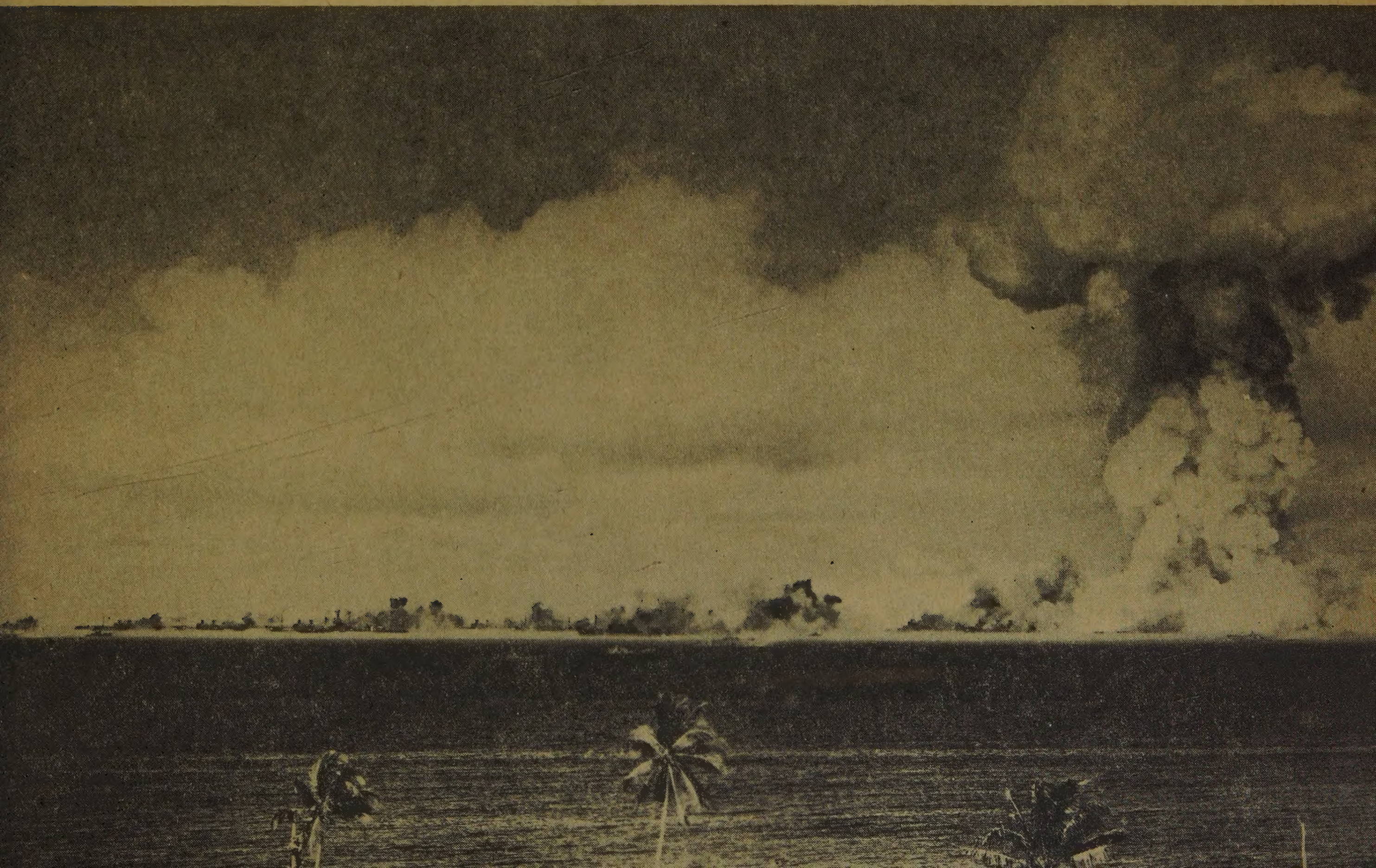


Figure 4. Cloud of radioactive gas ascending; "smoke" from ships consisting of dust, soot, and debris resulted from decompression after pressure wave

Electronics—Workhorse at Bikini

A staff of over 450 personnel, 75 of whom were civilians from the Naval Research Laboratory, the Signal Corps engineering laboratory, and 13 industrial and academic laboratories, was required to carry out the electronics activities of Joint Army-Navy Task Force One for Operation Crossroads. This article comprises parts of what was presented at a joint meeting of the AIEE New York Section, the New York section of the Institute of Radio Engineers, and the Radio Club of America on November 6, 1946. Donald G. Fink (M '45) spoke on television and remote control as it was used at Bikini; and T. D. Hanscome described the equipment used in the telemetering of air and water pressures, the telemetering of radioactivity, the study of electromagnetic effects including radio and radar monitoring, and the measurement of timing. Several phases of electronics as used in the control of the drone airplanes and the actual detonation of the bombs were outside of the jurisdiction of the electronics co-ordinating group according to Captain Engleman who presided over the meeting.

ON July 1, 1946, after months of preparation on a scale to equal some of the preparations for amphibious assaults during the war just ended, the fourth atomic bomb was detonated successfully over Bikini Lagoon in the Marshall Islands. Shortly after that, on July 25, the fifth atomic bomb was detonated in shallow water in the same lagoon. On these two days, Joint Army-Navy Task Force One, under the command of Vice-Admiral W. H. P. Blandy, Jr., United States Navy, carried out Test Able and Test Baker of Operation Crossroads.

These atomic bomb tests at Bikini were conducted primarily for the purpose of determining the effectiveness of this revolutionary weapon against naval ships and their equipment; to afford further training to the Army Air Forces in the use of the bomb; and to collect additional scientific data on atomic bomb explosions. These were the missions of Operation Crossroads, as decided by the Joint Chiefs of Staff.

The purpose of the electronic program of Operation Crossroads was twofold: first to expose electronic equipment of the Navy and the Army to the effects of atomic bombs and to assess the damage, and second to provide electronic systems for measuring and observing the technical effects associated with bomb explosions, such as water and air pressures, radio wave propagation, wave heights, and the like.

The basic job of the electronics program was to determine what happened to standard military electronic equipment when exposed to the air burst and underwater burst of the atomic bombs. The target ships numbered 75 in Test Able (air burst) and 73 in Test Baker (underwater burst). All of the electronic equipment normally installed on these ships, including radio transmitters and receivers, radar, sonar, loran, public-address and communicating equipment, was examined prior to each test and its condition recorded.

Prior to Test Able, 97 per cent of all the equipment was found to be in operating condition. In addition to shipborne equipment, electronic equipments of the Naval air arm, and of the Army ground forces, were exposed on the decks of various vessels and on Bikini Island. In all, this array numbered about 3,800 electronic equipments.

Some idea of the scope of the damage inspection job can be gathered from the fact that over 800 communications-type receivers were exposed, the radar equipment numbered nearly 300 major items, test equipment over 250 major items, and even specialized items like sonar and loran numbered approximately 50 major items of each type.

Following each blast the target equipment was inspected, at first visually and later, when power was available, by thoroughgoing application of test equipment. This job took a force of 150 specialists several weeks following each blast. The condition of each equipment following each blast was recorded in tabular form, requiring a report of 1,060 mimeographed pages for the Able test alone.

ELECTRONIC INSTRUMENTATION

While the primary purpose of the Bikini tests was to assess damage produced by the bomb at various distances, it was not sufficient merely to expose the equipment and examine it afterwards. This procedure would reveal what had happened, but would leave largely unanswered the question of how the damage was caused.

Essential substance of papers presented at a joint meeting of the AIEE New York (N. Y.) Section, the New York section of the Institute of Radio Engineers, and the Radio Club of America on November 6, 1946.

Christian L. Engleman, captain, United States Navy, is electronics co-ordinating officer of Joint Army-Navy Task Force One. **Donald G. Fink**, who joined Captain Engleman's staff and who was made officer-in-charge of all technical reports in the electronics co-ordinating group, is editor-in-chief of *Electronics*, McGraw-Hill Publishing Company, Inc., New York, N. Y. **T. D. Hanscome**, who was assistant electronics co-ordinator of the technical staff of Joint Task Force One, is principal physicist at the Naval Research Laboratory, Anacostia, D. C.

This "how" factor involved the values of pressure temperature, blast, and shock to which the equipment was subjected. Without such quantitative information, designers would find it difficult to improve the designs found inadequate. To permit interpretation of observed damage, a program of scientific instrumentation was set up.

In the field of electronics, this instrumentation program had five major parts:

1. Television for direct observation of the blast and its effects, and for measuring the heights of waves.
2. Telemetering of air and water pressures created by the explosions.
3. Telemetering of radioactivity.
4. A study of electromagnetic wave effects, including monitoring of radio and radar equipments operating during each blast, these being on ships and on one of the Bikini islands.
5. Precise measurement of the relative timing of various events connected with the explosion.

THE TELEVISION SYSTEM

Two light-weight television transmitting systems (type *ARK/ATK* or Block III) were set up on Bikini Island, about three miles from the blast center. These equipments weigh only 100 pounds, have a power output of 10 to 15 watts in the frequency range 150 to 270 megacycles, and produce a 350-line 40-frame picture using a standard iconoscope camera. The equipment was mounted atop 75-foot steel towers and so positioned that one camera viewed the target fleet, taking in about ten of the principal target ships at the center of each array, while the other was trained on the nearby beach to televise pictures of the waves caused by the explosions. Approximately 20 receivers were distributed among seven observing ships, including Admiral Blandy's flagship, the press ship, two official observer ships (military, scientific, and United Nations observers), and three "working" instrumentation ships. The receivers employ 7-inch green-phosphor cathode-ray tubes, and can tune to any of ten 8-megacycle channels separated 12 megacycles. Each receiver was fitted with one or more monitor picture tubes located at various points in each ship to permit as many as 100 observers to view the scene simultaneously.

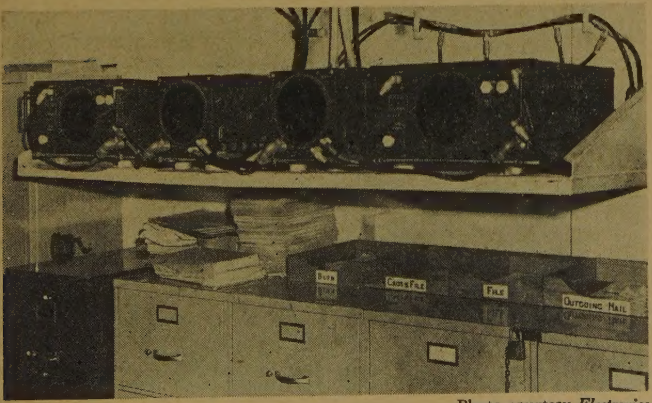


Photo courtesy *Electronics*

Figure 1. Pair of television receivers and associated monitors in the shipboard electronics laboratory office

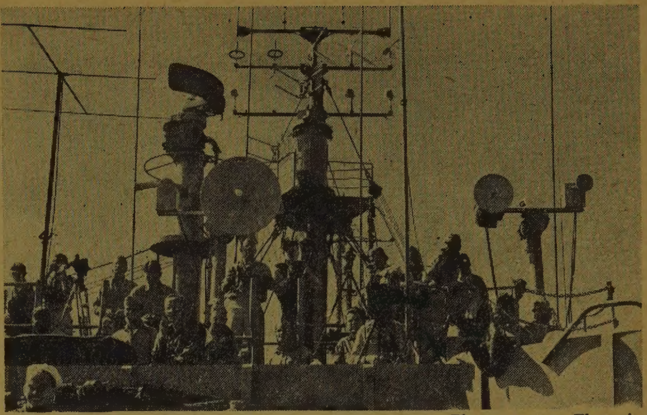


Photo courtesy *Electronic*

Figure 2. Radar platform of the USS Avery Island just before the Baker blast

One of the problems of televising the air burst was the intense light generated by the atomic fission. Advance information stated that at the 3-mile distance, bomb brightness would equal or exceed that of the sun for a period of several seconds. Since it was known that direct exposure to such light would burn the mosaic of the iconoscopes, tests were conducted at Bikini to determine the density of the optical filters necessary to protect the cameras. It was found that 100 per cent modulation of the television carrier occurred when a camera viewed the sun through a filter of density 2.1. It was also found that an illumination several hundred times that of the sun could be handled safely for a period of a few thousandths of a second. This was proved by exploding a 4-million-lumen flash bulb directly in front of the lens at a distance of one foot and noting the effect on the video waveform.

To protect the camera which viewed the air burst directly, a magnetically operated solenoid carrying a neutral-density filter of density 2.4 was positioned in front of the lens and controlled by a timing circuit having a delay of 13 seconds. The filter was positioned by a radio timing signal, scheduled for five seconds before the blast, and removed eight seconds after the blast. For reasons of safety and security, several of the observing ships were stationed at about 20 miles from the air blast. This exceeded the range of the 10-watt carrier, because the transmitter and receiver antennas were no more than 75 feet above ground. Accordingly, it was decided to operate an airborne television relay on the Stratovision principle. Transmitting equipment identical to that on Bikini Island was installed on two *PBM* Mariner flying boats. Standard Block III receivers, which had been installed in the aircraft to permit motion-picture photography of the television scenes, were connected to

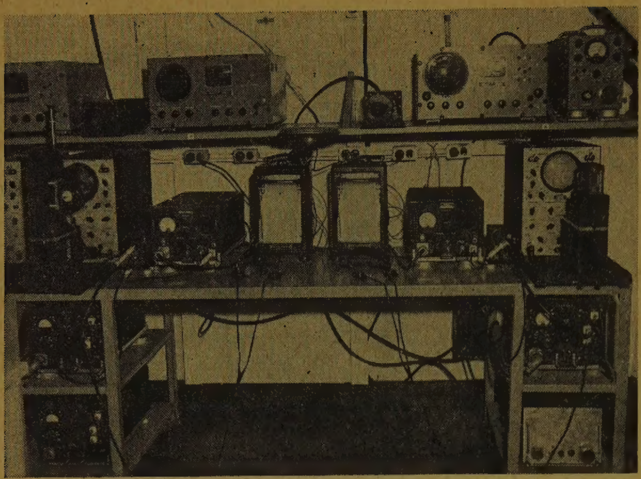
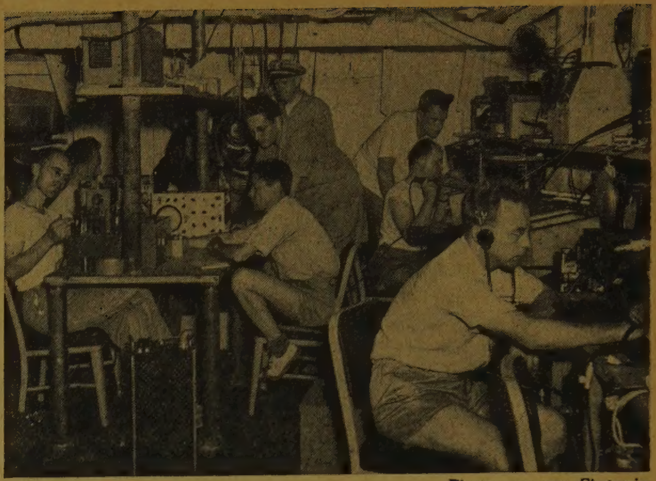


Figure 3. Monitoring gear; oscillographic cameras (left and right) and recording milliammeters (center)



Photos courtesy *Electronics*

Figure 4. Radio and radar monitor room aboard the USS Avery Island

the transmitters. The frequency separation between received signal and relayed signal was 24 megacycles, sufficient to avoid feedback difficulties. Excellent reception at the 20-mile range was achieved by this method, and recognizable pictures could be seen at 45 miles. During the Baker test, the ships were located at 10 to 12 miles, and the relay proved unnecessary when 3-element directive arrays were installed on the Bikini transmitters.

One of the outstanding aspects of the television project was the reliability of unattended transmitter operation. In each test the transmitters were turned on about 2:00 a.m., and the camera circuits adjusted without an image while darkness prevailed. Thereafter the transmitters continued to function without interruption, and without failure of any kind, surviving the effects of the blast and continuing to operate until turned off some 15 hours later. The images, while not of broadcast quality, were entirely adequate for the purpose and gave observers the first indication of the extent of the damage. The waves were of negligible height at the Bikini shore following the air burst, but were five to ten feet high following the underwater test.

BLAST MEASUREMENTS

For air blast measurements in Test Able a National Defense Research Council equipment designed at Princeton was provided. In this system the voltages of 18 bridge-type strain sensitive gauges fitted with diaphragms are linked by means of a single frequency modulated transmitter to a single receiver. Multiplexing is achieved by means of time sharing, that is, electronic commutators are provided at both transmitter and receiver to connect in sequence the gauges at the transmitter and the recording channels at the receiver in synchronism. Exact synchronism and great stability are maintained by means of an open sequence, that is, there are 18 intervals of measurement and an interval of rest and control before the sequence repeats. Each gauge is sampled some 500 times per second. The commutator rate is 10 kc. The receiver commutator is controlled entirely by the transmitter commutator in a manner similar to synchronous control of television receivers by main synchronizing pulses from the transmitters. Records were made on photographic paper using multichannel oscillographs.

The transmitter frequencies used were in the neighborhood of 70 megacycles. Each channel had a band width of approximately 200 cycles. In all 36 channels were used with gauges installed on two ships at different distances from the target center. In order to guarantee complete saturation of the limiters in the receivers, 600-watt amplifiers were used with the transmitters and directive antennas were used with the receivers on the *USS Avery Island.*

For water shock pressure wave measurements frequency-modulated transmitters in the 60- to 70-megacycle region were used (also with 600-watt amplifiers). Because a shock wave in water is essentially a discontinuity in the pressure occurring in a distance comparable to molecular dimensions, the rise-time of the pressure pulse depends on the size of the gauge used. Gauges available produced pulses having a rise-time in the order of ten microseconds. Considerations of circuits and linearity limited the bandwidth to 50 kc. From the mechanical viewpoint this bandwidth permitted adequate resolution. In the measurements made during the Baker test the adequacy of the bandwidth was borne out. The shape of the pressure pulse indicated that the sharp rise of the pulse contained the only significant high-frequency components. Six channels were used with six gauges mounted below the surface on or near two target ships at different distances from the target center.

High-speed film recorders using cathode-ray oscillographs were used to record the pressure during this test. Two recorders were used in parallel as insurance against possible failure of one. One recorder was designed and constructed at the Westinghouse Research Laboratory, the other at the Cornell Aeronautical Laboratories. The Cornell recorder operated with a film speed of 600 inches per second, the Westinghouse machine at about 200 inches per second. Both recorders easily could resolve a 50-kc sine wave.

The Navy type *JM*-4 sonobuoy (water-borne battery-operated transmitter) was used as a telemetering device to measure blast wave and shock wave velocity. In Test Able 20 of these sonobuoys operating in the region from 70 to 90 megacycles were used. They were anchored by pairs on a radius from the center of the target area. At each pair one hydrophone was suspended in the air and one suspended beneath the surface. The exact radial spacing between pairs was determined from low level aerial photographs taken just before Test Able. The pressure pulses as measured by the hydrophones actuated 20 frequency-modulated receivers installed on Aomoen Island (one of the Bikini group). The record of the pulses was made on photographic paper by means of string oscillographs. Thus from knowledge of the spacing of the buoys and the time of arrival of the pressure wave at each pair the shock wave and blast wave velocities could be calculated. Eight sonobuoys mounted on target ships were used in a similar fashion during the Baker test.

RADIOACTIVITY MEASUREMENT

An interesting application of telemetering was made to the measurement of radioactivity. The transmitter sections of a number of *SCR-694* pack sets were installed on ships of the target array. (Some sonobuoy transmitters were used also.) These transmitters were modified so that they could be modulated by Geiger-Müller tubes and by integrating ionization chambers or by a combination of both. The Geiger-Müller pulse or the pulse from the integrating circuit in the ionization gauge was used to modulate the carrier. The receiver sections of the *SCR-694*'s were used in conjunction with Esterline-Angus recorders to record the radioactivity level at selected points in the target area. This measurement was remarkably successful, in spite of the fact that the project was not begun until the *USS Avery Island* had left San Francisco. Under analysis, the data derived yielded results enabling one to predict the earliest time that it would be safe to approach ships upon which the telemetering transmitters were installed. For a short period after Test Baker many of the recorders

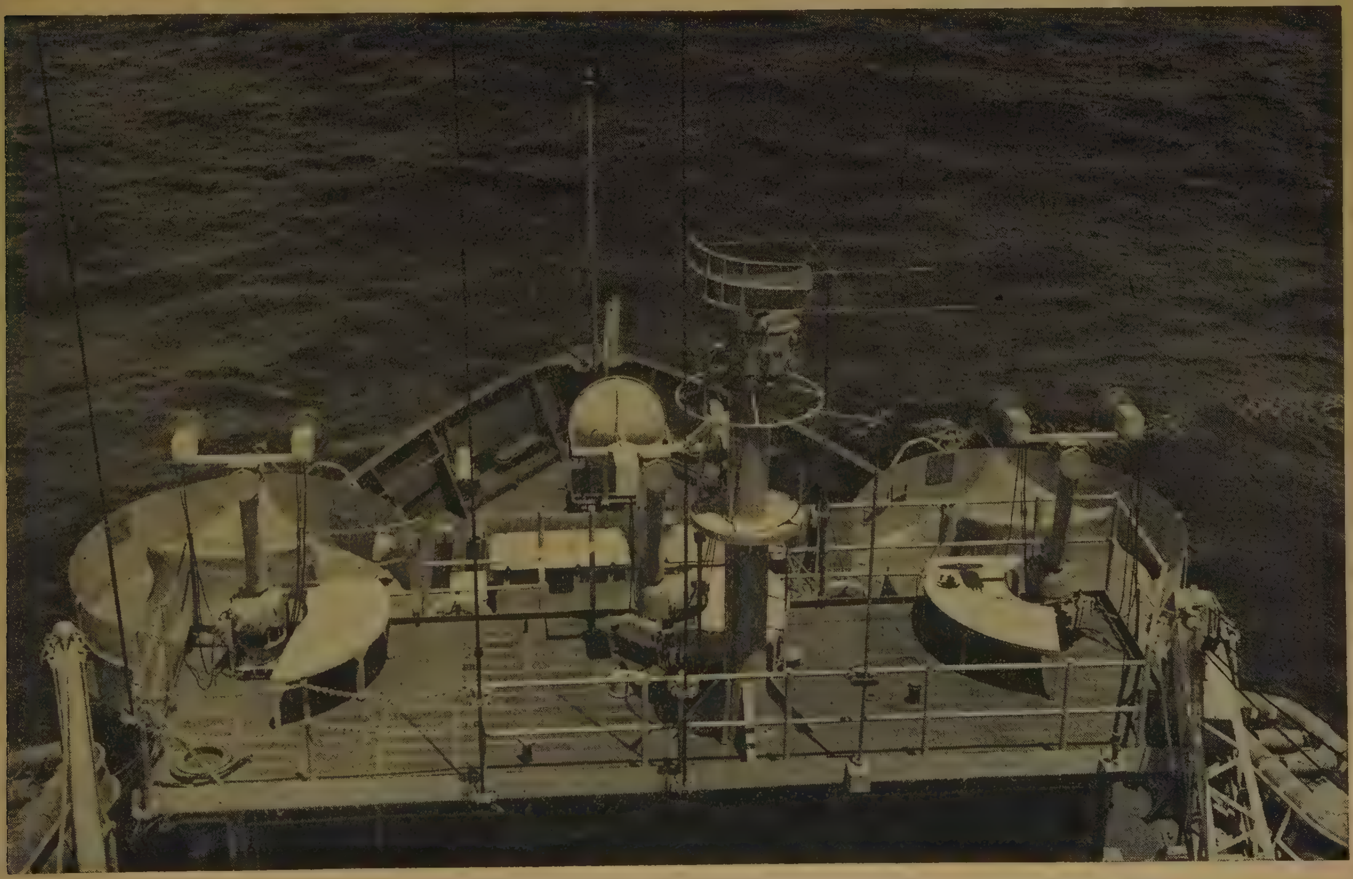


Photo courtesy *Electronics*

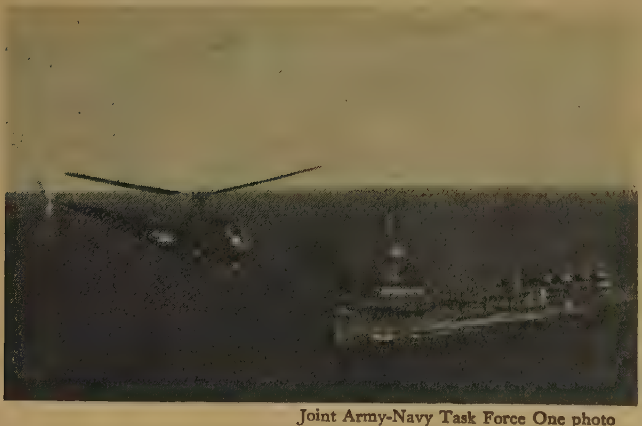
Figure 5. Bow of the USS Avery Island showing radar platform; whip antennas were for monitoring on 5 to 15 megacycles

were saturated (off-scale) because of the great intensity of radiation accompanying and immediately following the blast. Except for this, a complete record was made—there are many pounds of recorder chart to support this statement!

RADIO AND RADAR MONITORING

Considerable effort was directed to radio and radar monitoring. Selected radio, radar, and identification-friend-or-foe equipments in target ships were put into operation prior to both Able and Baker explosions. These equipments were monitored on the *USS Avery Island.* Continuous records were made of carrier level carrier frequency, pulse width, and repetition rate. These measurements were made in order to establish a connection between the damage sustained by the operating equipment and the bomb effects producing that damage. In addition to this, instrumentation was arranged to measure any effect the explosion might have on propagation. The frequencies covered by the monitoring project were the 5- to 15-megacycle communication band, the 200-megacycle range used by identification-friend-or-foe and low frequency radar and the 10- and 1-centimeter microwave radar bands.

Specialized radars operating at 10-, 3-, and 1-centimeter wavelengths were installed on Aomoen Island. The prime purpose of these equipments was to provide a record of the position of the target ships during those moments when the target area might be obscured by smoke or fog. The indicators of the Aomoen Island radars were photographed at several speeds by motion picture cameras and by single-frame sequence cameras. Shortly after the Baker shot, the cloud of radioactive fog passed over the island and fogged the film, however, since it was a high contrast record, the data were not lost. The entire installation on Aomoen Island operated unattended from early morning of the test days until the measured fuel in the power units was exhausted late in the day. Film was removed from the island by helicopter the day after the test in order to minimize fogging by radioactive dust and gases. The monitoring installations on the *USS Avery Island* monitored the Aomoen radar throughout both blasts.



Joint Army-Navy Task Force One photo

Figure 6. Helicopter was used to remove film from Aomoen Island to minimize fogging by radioactive mist

In addition to the radar and radio monitoring, both local and remote atmospherics measurements of natural static were made at the time of both tests. Also, extensive arrangements were made to provide radar observations of the cloud from various distances.

THE TIMING PROBLEM

A major problem that confronted all instrumentation groups at Bikini was the problem of timing. The unattended instruments were turned on in most cases by timing signals provided by the Los Alamos, N. M., field group. This in itself was a tremendous problem because of the large number of installations and the diversity of timing requirements.

For the information of those groups whose records were to be made with respect to worldtime or chronometer time, a special time record of the Baker test as made on the *USS Avery Island.* A frequency standard was used in conjunction with a 3-decade frequency divider to provide on an oscillograph chart a time interval record accurate to 1/100 second. Chronometer marks were inserted in this record using the chronometer key. These marks were accurate to 1/10 second. The chronometer rate was established and the consistent human error cancelled by making use of *WWV* transmissions on several nights preceding the test. (*WWV* could not be received dependably in the daytime.) All events including the time signals were recorded on the same multielement oscillograph.

REMOTE CONTROL

Remote control was used to guide drone boats in and out of the contaminated area to pick up water samples as a further aid indetermining radioactivity levels, and to aid in computing the efficiency of the atomic bomb. This equipment, adapted from the remote control equipment developed during the war, permitted the motor to be started, the anchor cable slipped, the throttle advanced or retarded, and the rudder turned right, left, or centered, and operated a pump for collecting water samples, all by pushbutton control from a vessel outside the lagoon. Airborne observers guided the controllers by radioing instructions to the control ship. This equipment operated successfully and permitted observation long before human beings could approach the contaminated area.

All of this complicated electronic equipment operated satisfactorily, with a few exceptions traceable to human error or to the fact that delicate equipment aboard target ships was put out of action by failure of power supply or by the blast itself. Interpretation of the results and correlation with the observed damage are now underway.

Functional Analysis of Measurements

I. F. KINNARD
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With the increasing demand for accurate measurements in all branches of the sciences, the many advantages provided by the use of electrical means in measurement have led to their general utilization in problems incorporating large numbers of physical quantities. Because the employment of electricity has complicated measuring equipment further, a practical system for analyzing measurement systems is needed. Through the use of functional analysis any measurement system can be considered as being composed of not more than three functional parts, thus reducing an almost unlimited variety of equipment to a relatively few fundamental types.

HISTORY tells us that measurement has been one of the principal foundations upon which the material progress of mankind has been based. It is only by carefully comparing or measuring the unknown in terms of some known quantity or unit that real knowledge is advanced. As our modern way of living increases in complexity, and as our knowledge of science and technology expands, measurements and measuring equipment have increased progressively in diversity and in complication. Better measurements have vitally aided our progress in understanding physical laws, in designing and operating new and improved machines, and in automatic control of processes and operations. In all fields of applied arts and sciences our rich store of knowledge is largely the result of our ability to measure.

Measurements were once simple and relatively few. With the development of practical applications of all branches of science, however, the number of quantities requiring accurate measurement has increased manyfold and now is almost without limit. Measurements on a large scale have been graduated from the laboratories to our workshops, factories, and even to our homes. They have become, in one way or another, a real and necessary part of our daily lives. Much measuring apparatus has become exceedingly complex. This is the result of a number of factors, including the necessity of performing new measurements inherently more difficult, and the need for greater accuracy and sensitivity.

Electrical means for assisting in the measurement of a large number of physical quantities now are utilized quite generally. Their use provides a number of outstanding advantages such as ready availability of measurement energy and superior flexibility. Moreover, electricity readily lends itself to remote operation of indicators, recorders, or controllers. This trend has complicated measuring equipment further, however, by adding many complex measurement systems and devices that have been designed for a great variety of purposes.

The method of analysis described in this article was developed in order to provide a clear presentation of the various functional parts of any measurement device or system, and to make available a common language of measurement terms and nomenclature for the group of measurement engineers with whom the author is associated. Although thus far it has been applied only to devices designed for the measurement of electrical or other physical quantities by electrical means, the general principles involved by no means are limited to the analysis of electrically operated equipment. It is hoped that the material presented herein will be of assistance to all designers and users who are interested in this very important and rapidly expanding field.

GENERAL FUNCTIONAL CLASSIFICATION

All measurement systems, simple or complex, can be considered as being composed of not more than three principal functional parts or groupings: namely, a primary detector, one or more intermediate means, and an end device. This conception is illustrated in Figure 1. The sequence of the measurement is from left to right, and all functional steps in the over-all operation logically fall into one of these groups. Although numerous measurements can be performed without the use of any intermediate means, all three general functional classifications very frequently are required to accomplish the desired result.

End Device and Primary Detector. A quantity is measured to obtain either an indication of its present value, a record showing time of occurrence, or to initiate a control operation. A mechanism that embodies one or all of these functions, therefore, is called an end device. This represents the result of the measurement and is of

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Material for the paper on which this article is based represents part of a study directed by the author and undertaken largely for administrative purposes. Various members of his staff assisted in the project but special acknowledgment is given H. C. Dickinson for his keen interest and valuable assistance.

primary interest to the user of the equipment. Everything else involved is for the purpose of suitably actuating the end device in proper relation to the quantity being measured.

When a measurement is made in whole or in part to control the measured variable, this operation is initiated at some definite point in the measurement sequence by means of suitable make-and-break contacts, pick-up coils, or other types of basic elements. The control initiator usually is included in the end device, but it may be associated with the primary detector or intermediate means.

The first operation in the measurement sequence is of particular interest. The basic elements involved must respond quantitatively to the measured variable in such a way that their operational output can be used to actuate the end device directly or indirectly. Elements performing this function are termed primary detectors of the apparatus under consideration.

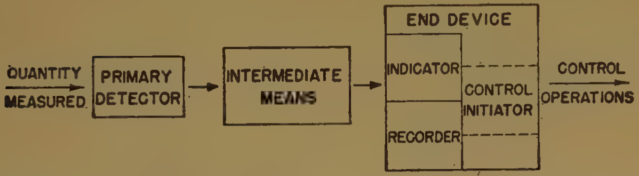

Figure 1. Schematic diagram of general functional classification

As previously indicated, a primary detector and an end device may constitute the entire measurement, particularly in the simpler measurement systems. In some instances the primary detector may be a separate element functioning independently of the actual end device, as in the lightmeter shown in Figure 2. However, it also may constitute an important functioning part of the end device itself, as illustrated in the directional gyroscope of Figure 3.

It should be emphasized that the conceptions of primary detector and end device are purely functional and that the grouping into which a given basic element falls depends entirely upon where and how it is used in a particular measurement sequence.

Intermediate and Auxiliary Means. In many instances the output or operational result of a primary detector, either because of its nature or because of its remote location, is not suitable to actuate the end device. Therefore, it becomes necessary to convert this output into some other quantity, to modify or amplify it, or to supply measurement energy to the system. All such operations are classified as intermediate means. The location and physical housing of the intermediate means is determined by convenience. It may be included with the primary detector or the end device, or it may consist of separate devices interconnected mechanically or electrically. Although such additional operations should be kept to a minimum because of the resulting increase in the complexity and cost of the device and the possible loss in measurement precision, much greater flexibility and sensitivity often can be realized from their use. Moreover, in some instances the very nature of the measurement makes the use of one or more intermediate means necessary. In the capacitance-type liquid-level gauge shown in Figure 4, for example, the intermediate means, an electronic oscillator, is necessary to act as a capacitance-current converter between the primary detector and the end device.

Occasionally it may be necessary to change the magnitude of the measured quantity so that its level is better suited to the primary detector. Equipment for this purpose includes such assemblies as instrument transformers, preamplifiers, and shunts, and may be either a separate unit or a built-in part of the measurement device. Functionally, it operates before the primary detector and is classified in a subordinate grouping as auxiliary means. It actually does not perform the initial step, or quantitative response, in the measurement sequence, inasmuch as it merely changes the level of the measured quantity.

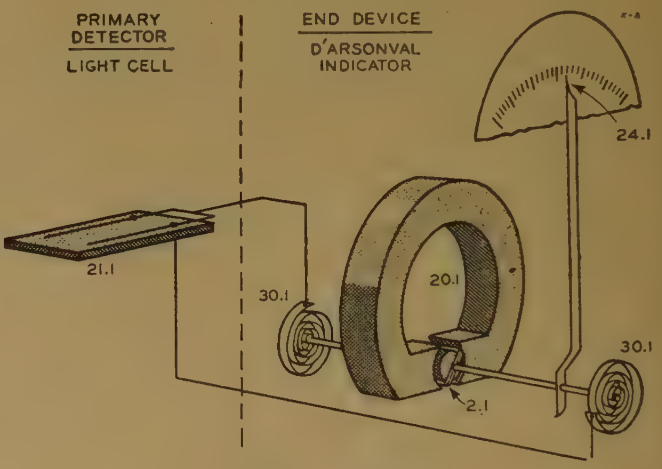

Figure 2. Lightmeter

2.1—Moving coil
20.1—Stationary field magnet
21.1—Photovoltaic cell
24.1—Moving pointer, fixed scale
30.1—Restoring-torque spring

The system of analysis described in the preceding has been applied to hundreds of different types of measurement devices and systems and lists of primary detectors, intermediate means, and end devices have been compiled. In general, it has been found that the number of functional types of end devices used is rather limited, whereas there is a much larger list of primary detectors available. Such classification is very useful to designers and users of measurement apparatus, because it reduces to a relatively few fundamental types what otherwise might appear to be an almost endless variety of equipment.

SPECIFIC FUNCTIONAL CLASSIFICATION

It is evident that the classification into general functions is not sufficient to supply a clear understanding of the exact nature of the device analyzed. By carrying the analysis one step further, however, each specific functional operation in the measurement chain can be identified and the main groupings can be broken down into distinct units termed basic elements which represent the smallest steps in the measurement sequence that it is convenient to consider.

A typical D'Arsonval recorder, for example, which, as a whole, is classified as an end device in the general analysis, can itself be broken down into eight functional units as shown in Figure 5. Each element listed is essential to complete the operation of recording the value of the measured quantity. In a sense, these elements may be termed the "building blocks of measurement."

A specific analysis of all measuring equipment previously considered from the standpoint of the general classification has been carried out, and the basic elements involved have been named, listed, and classified. A decimal index system has been established for convenience of reference and facility of adding new elements as required. It is interesting to note that all basic elements thus far identified can be classified under one of 92 specific types, and these, in turn, grouped under only 34 general functional headings. Although it is apparent that this list may have to be expanded somewhat as new devices are analyzed, the number of additions probably will be small inasmuch as experience has shown that nearly all new devices fit into the pattern of classification already established.

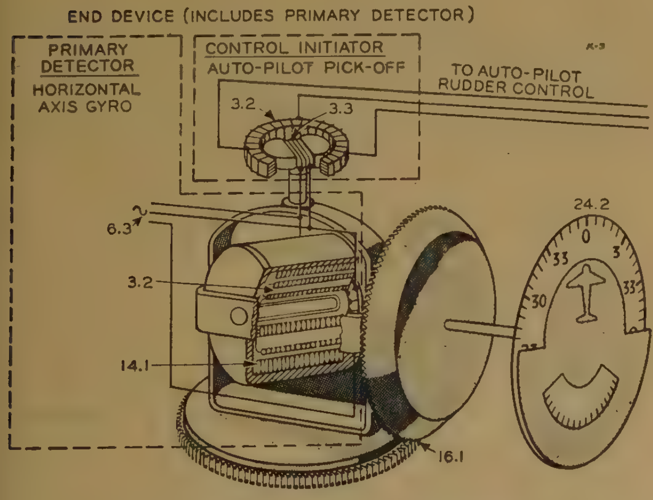

Figure 3. Directional gyroscope

3.2—Electromagnet stators
3.3—Electromagnet rotor
6.3—A-c source
14.1—Electrically-driven gyroscope rotor
16.1—Gearing
24.2—Fixed pointer, moving scale

COMPLETE ANALYSIS AND CLASSIFICATION

By combining the methods of general and specific analysis it becomes possible to show on one schematic diagram a detailed functional explanation of a complete measurement system, thus providing a standard method of presentation, as well as a basis for naming, listing, and statistically analyzing all the functioning parts of which a given measurement device is composed. An example of this complete analysis is shown in Figure 6 in which both of the methods outlined are applied to a typical photoelectric temperature recorder. Each significant step in the measurement sequence is indicated clearly by identifying the basic elements involved and marking them in accordance with the established decimal index system. The order of the tabulation, in general, corresponds to the flow of measurement energy from the first operation to the end result. In Figures 2, 3, and 4, the basic elements are listed below the diagrams. These illustrations, therefore, exemplify the application of the complete analysis and classification to different types of measurement equipment.

RELATED TERMINOLOGY AND LITERATURE

Wherever practical, the terms and definitions used in developing the method of functional analysis and classification of measurement apparatus have been kept in agreement with the established terminology of measurement.[1] Some modifications and adaptations have proved necessary, however. The new term "primary detector," for example, at first may seem an unwarranted departure from "primary element," which is the name that has been used for some time in connection with industrial process instrumentation[2,3] for the initial functional unit in a measurement sequence. This change was made, however, because, in the method of analysis described, the primary detector may consist of more than one basic element, and because the term "basic element," as defined, includes functional units anywhere in the measurement sequence and is not limited to the initial operation. "Primary detector" is used, therefore, to avoid confusion and to be more consistent with the names of the other two general groupings, the intermediate means and the end device.

Functional analyses of measurement and automatic control systems have appeared previously in technical literature.[2,4,5] While these analyses emphasize the value of considering measurements from the functional point of view, in general they have been limited to only a part of the whole measurement field and have been made to facilitate detailed discussions of the particular part involved. The functional analysis method presented herein is intended to be universally applicable to every device and system in the measurement field.

USES OF METHOD AND CONCLUSIONS

The method of analysis and classification of measurements that has been described was developed to provide

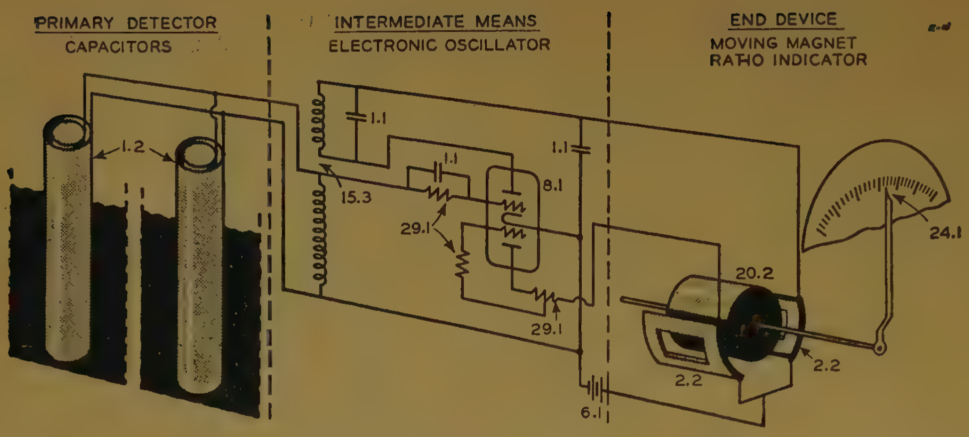

Figure 4. **Liquid-level gauge, capacitance type**

1.1—Fixed capacitors
1.2—Varying dielectric capacitor
2.2—Fixed coils
6.1—D-c source
8.1—Grid-controlled electronic tube
15.3—Mutual inductor
20.2—Moving field magnet
24.1—Moving pointer, fixed scale
29.1—Fixed resistors

an orderly approach to the problem of understanding and properly classifying the fundamentals of modern measurement systems. The many ramifications and the apparent complexity of this type of equipment make it imperative that terms be standardized more specifically than at present, and, therefore, a co-ordinated nomenclature is suggested.

The principal beneficial results obtained from this study may be summarized in the following manner.

Clearer Understanding. A useful medium is made available to depict individual measurement systems, showing in a logical manner, and in the proper sequence, just how they function. As a corollary, a specific use of words and phrases connected with measurement leads to verbal or written technical treatment that can be easily and commonly understood. It is hoped that this may have some helpful influence on future standardization activities.

By identifying common functional elements or assemblies of elements, a convenient method is provided for exploring and evaluating the whole measurement field and determining fundamental relationships in equipment having widely different applications. It is also of value in studying various designs of measurement apparatus intended for the same purpose and for determining basic similarities and differences. These ends can be attained by listing carefully the basic elements, primary detectors, intermediate means, end devices, auxiliary means, or control initiators of which the apparatus under consideration is composed.

Co-ordination and Standardization. As a result of a clearer understanding of the exact nature of the various functional parts of a measurement system, engineers can co-ordinate more effectively the design of specific basic elements, parts, or mechanisms. Co-ordination is used here in the sense of insuring that a specific part having a particular function be used as widely as possible in different apparatus wherever that function is required, thus minimizing minor variations in parts and preventing wasteful duplication.

The interrelation of basic elements, primary detectors, and other functional parts of a system is indicated clearly by the fact that only 92 basic elements of equipment are required to build up many hundreds of greatly diversified systems and devices. It would seem that engineers are concerned mostly with designing modifications of existing basic elements and regrouping them in order to accomplish a desired result. Only rarely is a really new one added.

All progress that can be made in co-ordinating and standardizing functional parts of devices and systems will be, of course, a powerful influence in arriving at better standardization of measuring equipment as a whole.

Research and Development. Well-arranged lists of basic elements and the general functional parts of all known measurement apparatus are very helpful to research and development engineers. They indicate

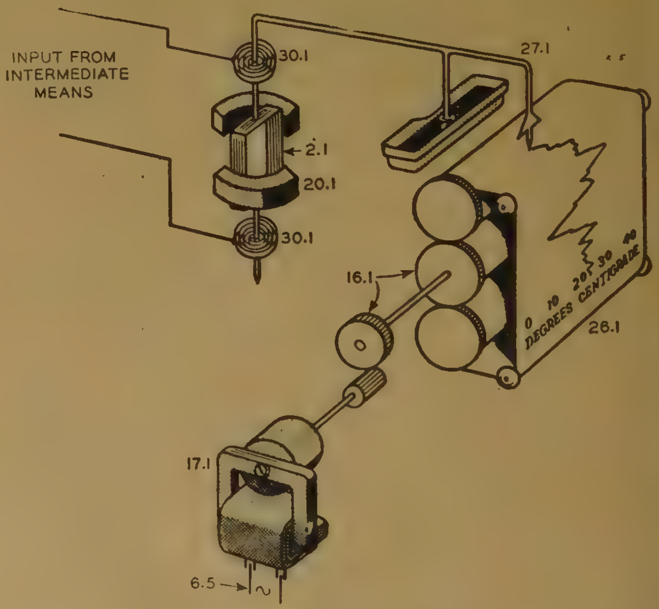

Figure 5. **Specific functional classification, D'Arsonval recorder**

2.1—Moving coil
6.5—A-c standardized-frequency source
16.1—Gearing
17.1—Timing motor
20.1—Stationary field magnet
26.1—Chart for marking
27.1—Curve-drawing means
30.1—Restoring-torque springs

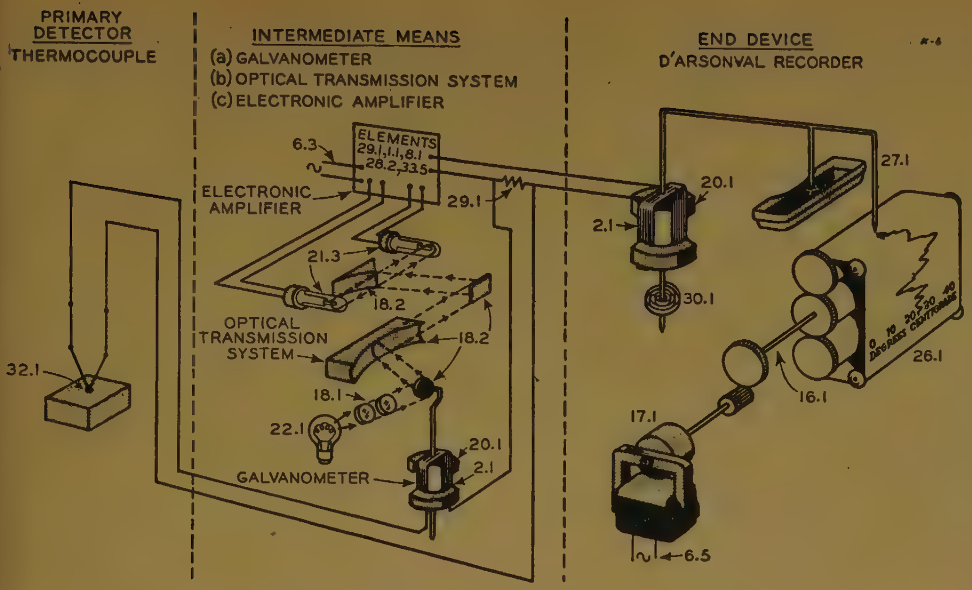

Figure 6. Photoelectric temperature recorder

1.1—Fixed capacitors
2.1—Moving coil
6.3—A-c source
6.5—A-c standardized-frequency source
8.1—Grid-controlled electronic tubes
16.1—Gearing
17.1—Timing motor
18.1—Lenses
18.2—Mirrors
20.1—Stationary field magnet
21.3—Photoemissive cells
22.1—Electric lamp
33.5—Power supply transformer
26.1—Chart for marking
27.1—Curve-drawing means
28.2—Electronic rectifier tube
29.1—Fixed resistors
30.1—Restoring torque spring
32.1—Contact thermocouple

clearly what is available and where new development or invention is necessary. Furthermore, the general viewpoint that can be gained from an analysis such as outlined enables an engineer to focus his attention directly on a desired specific objective and to see it in proper relation to the problem in hand and to the entire measurement field.

Application and Service. In the selection of measurement equipment for a specific purpose the functional analysis method can be helpful in several ways. The simplified functional diagrams should aid in understanding and choosing the proper instrumentation and in maintaining it in service. Evaluations and comparisons made possible by the system described aid materially in answering such questions as the following:

How direct is the measurement?

Is there any undue complexity, especially in intermediate means?

Are the basic elements inherently simple and reliable?

Is the design well-co-ordinated?

What auxiliary means, or power supply, is necessary?

Correct answers to these and other pertinent questions can be expedited if the application engineer is familiar with the idea of functional analysis and uses it carefully.

Data and Statistics. Considerable use already has been made of the systematic classifications and tabulations of measurement of functional parts for purposes of filing and cross-indexing. In addition to being indexed by name, data on primary detectors and end devices, for example, also can be classified according to the quantities to which they respond, while that on intermediate and auxiliary means can be indexed relative to the functions they perform. Basic elements can be listed specifically and each one subdivided into detailed variations as far as desired. All technical information available can be indexed so that it is identified readily with the pertinent basic elements.

General. The benefits realized from the functional analysis and classification of measurement systems and devices will depend a great deal upon how thoroughly it is studied, understood, and applied in a given organization or industry. In this article it has been possible to present only a small part of the work that has been done on the subject. It is likely that the point will be raised that nothing really new or radical has been presented. In one sense this is true. What has been attempted, however, is the collection, analysis, systematization, and organization of information, methods, and nomenclature that have been used in the art, but used in an unsatisfactory and indefinite manner. In doing this it has been found necessary to coin some new words and phrases and to give these, as well as those commonly used, specific meanings and definitions. It is believed, too, that a complete analysis consistently and systematically carried out from the functional viewpoint is new. Actually, the method already has proved very useful in a practical manner. Although, thus far, little thought has been given to the matter, it is also probable that the basic principles described in this article can be extended advantageously to apparatus and equipment quite outside the measurement field.

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Engineering and Quality Control

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FOR speed and economy in putting any product into quantity manufacture, there must be some technique for quickly locating and remedying defects. After production is established, the same technique is valuable in improving both product quality and output. Quality control is the name given to a new technique developed for these purposes which employs statistical methods.

The basis of quality control is the study of variations in process. Instead of asking how many pieces pass inspection, we ask, how much do the pieces vary? Also, what are the causes contributing to the observed variations? How does the variation in each process compare with reasonable expectations? Are the specified tolerances right for the processes used? Are the inspection methods adapted to reveal all possible defects?

Quality control, a technique based on a study of variations in process, utilizes statistical methods for detecting defects in quantity manufacture. However, it is a theory founded on the elementary laws of chance and thus a knowledge of these laws is of invaluable aid to the engineer who must specify the required tests, adapt his designs to the tools available, and adjust his tolerances correctly.

The study of variations has assumed a new importance since the development of highly complicated assemblies, or systems employing many different parts. Besides interchangeability of supply parts, it is essential that tolerances on the different pieces be chosen to give the best over-all cost and performance. Quality control, therefore, extends to the development of specifications with plus and minus limits.

In these studies, a knowledge of the laws of chance is invaluable. The expert knows that a test record different from the established mean by more than four times the standard deviation is positive proof that something is wrong. It is as much a signal for action to him as an air raid alarm. He knows that it is an even bet there are at least six per cent defectives in a new lot, even though ten samples picked at random are all good. He knows how to analyze each operation and each supply source, tracing back from the point where a defect first is located, to find and remedy the trouble with the least delay. And, he knows how to spot-check vital processes to note the first indications of pending trouble.

To make quality control effective requires teamwork. The engineer must specify the required tests, adapt his designs to the tools available, and adjust his tolerances correctly. The manufacturer must choose his machines, gauges, and processes to the best advantage. The inspector must devise the best techniques for measuring each element and keeping track of all sources of variation. The laboratory must specify and test incoming materials and treatments to ensure their uniformity.

Thus, to control the quality of the final product it is necessary to control the quality of the product elements in all stages of the manufacturing cycle; from the conception of the engineering design through the final assembly. In the past, the factory often has been held responsible for errors in engineering design, material ordering, planning, and methods; errors which were made in the beginning but which remained undiscovered until the product actually came through the production lines. It is important, therefore, that the principles of statistical quality control be understood and used by all those concerned in every stage of the manufacturing process.

THE ELEMENTARY LAWS OF CHANCE

The theory of quality control has been built up to a high degree by statisticians, but it all is founded on the elementary laws of chance, which every one can understand. These elementary laws can be stated briefly as follows:

1. The arithmetic mean of a series of measurements is the most likely true value; if there is no reason for expecting dissymmetry.

That is, if successive test readings are 64, 70, 66, and 68, then 67 is the most likely true value.

2. Another way of expressing the foregoing is to say that the most likely value is that making the sum of the squares of the errors a minimum.

In example 1, the successive errors from the mean are -3, 3, -1, and 1. The sum of their squares is 20. If 68 were chosen as the true value, the errors would be -4, 2, -2, and 0, giving 24 for the sum of their squares.

3. The chance of events *A* and *B* both occurring is the product of the chance of *A* occurring by that of *B*.

For example, if a die is thrown once, the chance is one in six that three will come up. If it is thrown twice, the chance that three will come up both times is only one in 36.

Essential substance of a paper presented during the quality control course of the Rochester Institute of Technology at the International Business Machines Homestead, Endicott, N. Y., September 9, 1946.

P. L. Alger is staff assistant to the manager of engineering, apparatus department, General Electric Company, Schenectady, N. Y.

4. The average variation in a mixed lot is the average of the variations in the separate component lots.

For example, suppose two machinists are making equal numbers of shafts to the same drawing, and the inspector finds they both make the same diameter on the average. If A's shafts vary 3 ten thousandths, and B's vary 5 ten thousandths, then the mixed lot of shafts will have a variation of 4 ten thousandths.

5. The variation in a product undergoing successive operations is the square root of the sum of the squares of the variations in the different operations.

For example, suppose the average error in making a part is 0.5 mil, and subsequent heat treating causes an average distortion of 1.2 mils, then the average error in the finished pieces is 1.3 mils.

6. Under the normal law of probability, the chance of an error lying between $x-(d/2)$ and $x+(d/2)$ is given by a bell-shaped curve, whose equation is

$$P=\frac{0.40 d e^{\frac{-x^2}{2\sigma^2}}}{\sigma}$$

where σ is the standard deviation (square root of the average of the squares of the errors).

From this may be derived the following:

The "probable error" (than which there are as many larger as smaller errors) is 0.675σ.

The average deviation is 0.80σ, and the chance of an error greater than

0.675σ is 0.50
0.80σ is 0.42
1σ is 0.32
1.5σ is 0.13
2σ is 0.045
3σ is 0.0027

7. A sample or lot having an error from the mean greater than 3σ is called a "maverick," and is taken as positive proof of a significant variation in the production process.

8. If a small number of defectives is found in a sample taken from a large lot, it is likely that the proportion of defectives in the lot will be greater than those indicated by the sample. This principle is illustrated by Table I. Data for this table were furnished by charts in a book by Colonel L. E. Simon.[1]

Table I

Sample Size n	Number Defective c	Probability That Fraction Defective in Lot Is Less Than the Tabulated Value				
		0.005	0.10	0.50	0.90	0.995
		Fraction Defective				
1	0	0.0025	0.050	0.29	0.69	0.93
3	0	0.0013	0.026	0.16	0.44	0.74
10	0	0.00045	0.0095	0.060	0.19	0.385
100	0	0.00005	0.001	0.0069	0.0225	0.051
1	1	0.070	0.31	0.71	0.95	0.9975
3	1	0.030	0.14	0.39	0.68	0.89
10	1	0.009	0.049	0.148	0.31	0.50
100	1	0.001	0.0052	0.0165	0.038	0.071
3	2	0.11	0.32	0.61	0.858	0.97
10	2	0.033	0.105	0.24	0.415	0.615
100	2	0.0032	0.011	0.026	0.052	0.089
3	3	0.26	0.56	0.84	0.974	0.9987
10	3	0.069	0.17	0.325	0.51	0.70
100	3	0.0069	0.017	0.036	0.065	0.105
10	5	0.17	0.32	0.50	0.68	0.83
100	5	0.0155	0.031	0.056	0.090	0.135
10	10	0.615	0.81	0.94	0.99	0.9995
100	10	0.044	0.070	0.105	0.15	0.20
100	20	0.115	0.157	0.203	0.26	0.32
100	30	0.197	0.25	0.30	0.365	0.43
100	50	0.375	0.44	0.50	0.57	0.63

SAMPLING

The engineer who studies the foregoing relations, particularly Table I, will discover many delightful possibilities for applying this theory in design and development work. Things which used to be matters of opinion now can be reduced to numerical calculation, and small differences in process can be evaluated quite exactly, by the simple process of reducing a mass of data to its basic elements of averages and standard deviations.

The first step in applying these laws to quality control is to take a number of pieces from the production line, and carefully measure some dimension or quality of each piece. Then, by calculating the average value, X, and the average error from the mean, E; or the difference between the highest and lowest values, called the range, R; two numbers are obtained which measure the uniformity of the material or manufacturing process. For small samples taken at frequent intervals, the range is generally most useful, while for large samples and for more exacting work, it is often desirable to calculate the square root of the average of the squares of the errors, which is called the standard deviation, or σ.

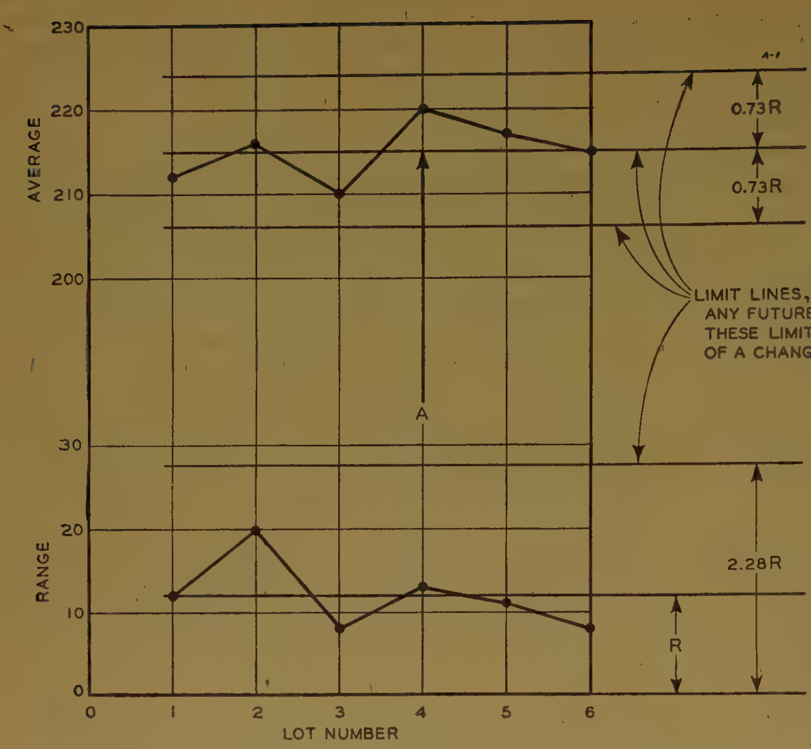
By taking additional samples from production at a later time, and comparing the results with those of the first sample, it can be determined whether the process is uniform or is continually varying—that is, out of control. By repeating the measurements on samples made by different operators, or with different tools, or some process change, the effects of any desired change in manufacture can be determined.

In making these comparisons, questions immediately arise, such as how many pieces must be measured to ascertain the true variation in the process; or how much variation in the range of the sample is necessary to prove that the manufacturing process has changed significantly.

Without going into the mathematics, it is sufficient to say that tables and charts are available in American Standards Association Standards Z1.1 and Z1 2 and elsewhere, which answer these questions for ordinary purposes. The important thing to remember is that, if any one measurement is found to be more than 3σ away from the mean of previous measurements, it is practically a certainty that a significant change has occurred in the process.

QUALITY CONTROL PROCEDURE

In practice, therefore, the thing to do is to establish a systematic procedure for taking samples, measuring them, and plotting the results on charts; so that the history of the process can be seen at a glance, and any variations of importance can be spotted before they become serious. To do this, both control charts and distribution curves are useful.



Upper chart shows average hardness values for successive groups of four tests

Lower chart shows the range, or maximum difference in hardness, between samples in each group of four

Figure 1. Control chart of Brinnell hardness values

Control Chart. The procedure is to take from each batch of material four or more random samples, and make exact measurements of their properties. The measurements preferably will consist of a failure limit, such as breaking or puncture strength. The size, or hardness, or any definitely measurable quantity may be used, however.

The average value A obtained from the group of four or more samples is recorded, and also the maximum difference, or range R, between the highest and lowest measurements.

These A and R values are plotted against time, or batch number, and the points connected by straight lines; forming a control chart* (Figure 1).

Interpretation of Control Charts. Errors or changes in process are indicated whenever either the range or the average of a group departs materially from the normal. If the range changes without affecting the average, there is indicated some local difficulty, such as tool backlash, or nonuniform furnace temperature, or inaccurate measurements, or poorly-mixed material. If the average changes without affecting the range, there is indicated a drift in the process, as may result from tool wear, change in atmospheric conditions, wrong setup, or change in the raw materials.

After some experience has been gained the control chart provides a means of noting just when a change in process occurs, and catching it before production has gone too far. If records of the manufacturing processes are kept, so that changes can be correlated with the chart indications, it is possible to find and adopt improvements in process as well as checking process defects.

Distribution Curves. Another way of analyzing data is to arrange the test results from 25 or more samples in the order of their numerical value, and plot the number of tests of each value vertically against the measured value itself horizontally. The resulting chart, called a distribution curve, normally has a bell shape with the maximum point close to the grand average of all the readings (Figure 2).

Subtracting the grand average value from each of the measured values, a tabulation of the errors from the mean is prepared. The arithmetic average of all of these errors, taken regardless of sign, gives the average error, E. The rms error or standard deviation is nearly equal to 1.25 times this average error, if the distribution curve has the normal shape. The rms error is calculated by squaring the individual errors, adding them, dividing by the total number, and taking the square root of the quotient. This process may be performed occasionally, to be sure that the distribution is of a normal character, but usually it is sufficient to assume the rms error is equal to 1.25 times E.

Interpretation of the Distribution Curve. The value of the distribution curve is that it enables the practical limits or tolerances of the material to be established, and an estimate of the probable number of future defects to be obtained.

For example, it is normally expected that about 11 per cent of all of the tests will depart from the average by more than twice the average error, equal numbers being on the high and on the low side. Also, not more than two per cent will depart from the grand average by as much as three times the average error. It is, therefore, customary to set the specification or required properties so that the average test results will exceed the requirement by at least four times the average error.

Hence, the "quality index" of the material or process may be defined as

$$\text{Quality index} = \frac{\text{Average failure level} - \text{Required level}}{\text{Average variation in failure level}}$$

and this should be greater than four in all cases. Higher values, of five or more, are required, of course, for vital parts.

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* Instead of R, the average deviation, E, or the standard deviation, σ, may be used.

Any improved uniformity in the material or process will reduce the necessary safety margin, and so permit economy in the design.

CONCLUSIONS

Summing up, this procedure establishes, first, the uniformity between successive lots of material, and, second, the width of tolerance band required to assure any desired level of per cent defective.

The control chart detects changes in process, and so enables improvements to be introduced without delay. The distribution curve calls attention to undue variations and suggests studies for improving the uniformity. The usual inspector's report, showing defects at the level of requirements, is a post-mortem account; whereas the control chart, showing defects at a level well above requirements, is a forecast. The forecast tells when defects are going to be found at the requirement level by measurements on pieces that are still satisfactory. Thus, the control chart procedure introduces a new order of economy and control into manufacturing processes.

The advantages are of the same kind as those obtained with the automatic steering which is actuated by the rate of change of the ship's direction, instead of the visual control obtained by the pilot's observation of the angle of yaw itself.

Taken together, the control chart and the distribution curve provide quality indexes, or numbers, that measure the uniformity of different materials, different vendors, different operators, or different processes; so permitting ready evaluation of alternatives, and giving the planners information to work to in laying out manufacturing processes.

It must be recognized, however, that the statistical method for controlling quality, though extremely useful in discovering and measuring the causes of control variations, is not a cure-all for manufacturing troubles. Quality is not improved, nor costs reduced, nor losses eliminated by the analysis of the problem, but only by the corrective action taken on the basis of this analysis. The direction of such corrective action requires intelligence, experience, co-operation, and co-ordination among all the individuals concerned.

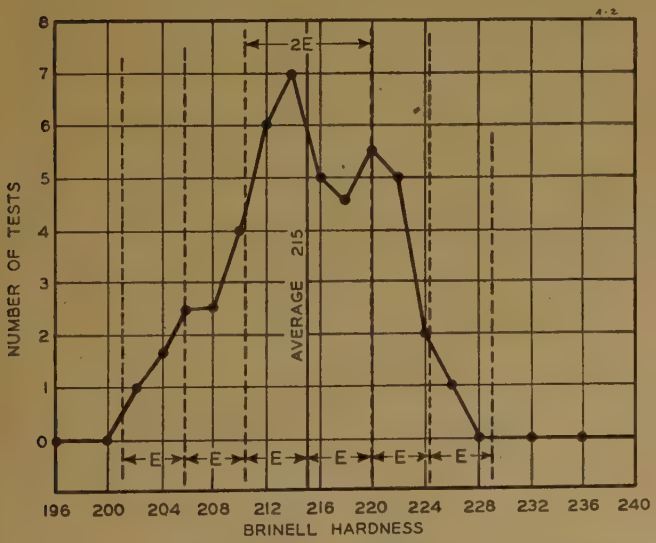

Figure 2. Distribution curves of Brinell hardness values

48 tests: Average hardness = 215

Average variations = E = 4.67

Rms variations = σ = 5.75

REFERENCE

1. An Engineers' Manual of Statistical Methods, L. E. Simon. John Wiley and Sons, Inc., New York, N. Y., 1941.

Heating With a Heat Pump

House heating by extraction of heat from the earth through a circulating refrigerant has proved practical and economically feasible in a test conducted during one season in Indianapolis, Ind., according to an article by A. C. Crandall, vice-president, Indianapolis Power and Light Company, Indianapolis, in *Electrical World* for November 9, 1946. Records show that during the 8-month heating season, although outside temperatures dropped as low as ten degrees below zero, inside temperature was maintained at a constant 72 to 74 degrees.

Natural heat of the earth is transferred into the heating system by circulating a refrigerant through a copper coil system buried in trenches outside the house. A condenser then replaces other means of furnishing heat in a standard warm air heating system. This method puts into the house from $3^1/_2$ to 4 times the equivalent heat used by electric equipment. The 350 to 400 per cent of heat delivered from the energy used for operation compares to the average fuel furnace delivery of about 50 to 60 per cent of the heat in the fuel. Calculated performance data on heat delivery during the test indicate an actual British thermal unit input per degree-day of 10,300, and an actual consumption per degree-day per thousand British thermal units of 0.081 kilowatthour.

The system utilizes a 3-horsepower motor which drives the compressor to pump liquid refrigerant through the tubing and condenser. House air is circulated through the condenser unit and into the air ducts, with filtering and humidity control arranged as in other heating systems. During the summer the process is reversed and the condenser becomes the evaporator and the earth coils the condenser, thus removing heat from the house.

For an account of the use of a heat pump system in an office building, see *Electrical Engineering*, October 1944, page 361.

Rural Electrification and Electroagriculture

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A DISTINCTION is made between "rural electrification" and "electroagriculture," the former being the art and the business of bringing electric service to the rural area and to the individual consumer in that area, the latter being the art and the business of using electric power for farming.

In both of these fields there are specific problems for the electrical engineer, some old, some new, some partly solved, others as yet unsolved, and still others which have not been stated definitely yet.

There are collateral problems between the two fields. One of the problems is the case of industrial loads supplied from rural lines. Offhand it would seem that a sharp line of demarcation between industrial load on the farm and that in urban areas would be important only for the purpose of statistics and economics but not for engineering purposes. However, occasionally specific engineering problems arise in connection with industrial loads on the farm. Even though very few such specific problems have as yet been crystallized, indications are that many new ones will arise as the farm load grows.

The rural circuit offers important engineering problems commonly overlooked; problems which can stimulate and challenge the electrical engineer, particularly the young engineer.

Electroagriculture and rural electrification offer a challenge and an opportunity to the electrical engineer. A great deal has been done by basic research, and many results of this research are available for the engineer to pick up for industrializing. It is surprising to find how little engineering has been applied to the problem of food production, food distribution, and food preservation. This art is only in the process of becoming engineering. It is the ultimate job of the engineer to make food independent of climate and independent of weather. It is not expected that such a revolution will be brought about in a day or a year, and it would be premature to suggest at this time how this will be brought about. But when hundreds or thousands of engineers begin to think about it seriously and continue thinking about it for 25, 50, or even 100 years, they eventually will solve the problem as they have solved many more difficult problems in the past. But the time is definitely at hand to begin engineering thinking.

Continuity of service to the farm is of prime importance. This continuity of service however, must be rendered at a low cost. In the case of the rural primary circuits, there is no diversity of protection schemes; there is only the fuse, the circuit breaker with a series coil, and possibly a thermal tripping device. Thus the engineering problem of the rural circuit is in some respects more difficult to solve than that of the 460-kv line.

HISTORY

It is evident that we are dealing here with a new industry, the electroagriculture industry. A new industry calls for new engineering treatment. Only a few years ago few items of electrical equipment for specific use on the farm were manufactured for the market by quantity production methods. American manufacturers thought that there was no market for such items. Competent hard-working men in agricultural colleges developed some fine designs, but there were no manufacturers willing to produce them. Here one of the difficulties encountered is the policy of some schools not to permit members of the faculty to secure patents on inventions. It is done with the best intention. They feel that a development made in a public institution should be available to everyone. However, this very policy prevents many a good idea from being put to general use. No invention is ever ready for the market. Expensive development usually is called for. A manufacturer cannot be expected to spend great sums on such development unless he has some exclusive patent protection. This applies also to a so-called public patent on which everyone could secure a free license. The best the college men could do was to send farmers the designs and specifications for homemade equipment. It became evident that if the American farm was to be electrified, it would have to be done by American manufacturers. But there was such a great diversity of ideas among agricultural experts and colleges that manufacturers hesitated to invest in tools for quantity production of any one design.

However a survey was made among colleges in search of new developments which might be ready for manufacturers to develop for quantity production. The report was distributed among manufacturers and several items now are being studied by them. It may be recorded that the American manufacturing industry finally did create this new industry during the war years, the most difficult imaginable time for such a creation.

For example, during the war the electric welder became a very important tool on the farm for the repair of

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Essential substance of paper 46-184, "Specific Engineering Problems in Rural Electrificaton and Electroagriculture," presented at the AIEE Pacific Coast meeting, Seattle, Wash., August 27–30, 1946, and published in AIEE TRANSACTIONS, volume 65, 1946, pages 1065–73.

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damaged equipment because the farmer was unable to get either new equipment or repair parts. No data were available to advise the manufacturers of the type of welders which could be supplied properly from rural power lines. In many instances the welder loads caused distribution transformers to burn out, disturbances of voltages, and similar nuisances. An investigation was made on which was based a specification prepared in cooperation with manufacturers and this specification eventually was accepted by the National Electrical Manufacturers' Association (publication 45-105, September 1945). Now the manufacturer can proceed with quantity production and the farmer can get a welder which will not disturb the power system.

NEEDS OF ELECTROAGRICULTURE

In an industry such as this, which is still partly in *statu nascendi*, it would be premature and inadvisable to establish rigid standards which might interfere with the creative imagination of the engineer and inventer or with creative competition which is needed for progress. However, some basic standards for performance as well as size and quality of material are needed to make it possible for the buyer to judge quality. Commercial test procedures also are needed for determining the service the buyer may expect an item to render.

Attention may be called to a few specific items for which there is immediate need. At present, freezing, cooling, heating, lighting, water pumping, and similar electrical applications on the farm are mere adaptations of developments made for city use. Engineers should develop equipment for the specific purpose. Good results would be inevitable. Numerous specific problems no doubt soon will be crystallized in relation to the electric motor and the motor control equipment on the farm. The problem of power factor control, limitation of starting current, and similar specific problems are now ready for investigation in a similar manner as the welding problem was investigated. One item, the need for which has been known for some time, is a simple and inexpensive means for stopping a motor automatically when the load is finished, as for instance for feed grinding and sawing wood, where time clocks are not suitable. One or more such devices are already on the market. But more designs for quantity production are needed.

Today, no one will dispute that sanitation is one of the most important requirements of human beings if they are to live on a level higher than that of pigs. The most important need is perhaps for a small electrically driven water pump, simple and low priced, to make it possible to introduce a minimum amount of sanitation even in the poor farm shack.

A small milk pasteurizer for the farmer who has only a few cows is needed badly. The present difficulty is that in most places a curve-drawing thermometer is required which costs more than the whole pasteurizer would. The problem is either to develop a cheap temperature recorder or an electronic pasteurizer which does not require temperature recording and on which it would be possible to secure approval upon presentation of competent test reports.

The problem of control of off-peak water heating on the farm has not been solved yet. For various reasons, clock control has not become popular. What is needed is a device which will disconnect the water heater upon the expiration of a definite time after the total load on the service transformer has reached a prescribed limit, and to reconnect the water heater as soon as other loads have been reduced. This would permit control regardless of the time of day or night. The principal difficulty in solving this problem is the fact that the device would have to be both simple and inexpensive to be suited for farm use.

Off-peak house heating has been tried, but in some cases it turned out to be peak-load. In many parts of the country the heat pump eventually may become the best method of heating and cooling farm houses and other farm buildings.

FIRE HAZARD

Fire hazard on the farm is far more serious than in the city. Many farmers would like to eliminate overhead secondary distribution lines between buildings, because of the hazards of lightning, icicles, trees falling on the conductors, and roosting chickens or other birds. For single-phase circuits it is conceded generally that an underground cable made up of one insulated conductor and one parallel bare conductor would offer the best lightning protection. Manufacturers are now busy at work on the development of an economical conductor of this nature, and it is hoped they soon will be able to place one on the market which will meet the approval of the authorities. This cable should be ratproof and gopherproof. It also should be frostproof, to make it unnecessary to dig below frost line.

Perhaps the field of freezing and cooling offers greater opportunities than other items for invention, improvement, and development. It is important to repeat that while centuries have been devoted to the engineering of controlling temperatures upwards, the engineering of controlling temperatures downwards is of comparatively recent origin.

It is estimated that a total of 60,000,000 rats on the farm cost the American farmer about $65,000,000 a year. It is indeed surprising that with this enormous amount of money involved, to say nothing of the danger to human health, American engineers have not tackled the problem yet. At least two types of electric rat catchers are known to exist and are reported to have given satisfactory results. American manufacturers should concentrate on the study of this problem and attempt to develop electric rat catchers which could be manufactured by quantity production methods and which could be made available at reasonable prices.

The study of the possibility of a small storage-battery-driven tractor has been delayed by the fact that some new lightweight batteries developed during the war are still military secrets. As soon as such batteries are available, the study should be continued. The convenience of electrical control certainly promises considerable advantages. Storage-battery charging would be excellent night load.

The application of high frequency to various purposes on the farm has not been studied sufficiently yet; neither has that of ordinary light, or infrared and ultraviolet radiations.

PROBLEM OF RURAL ELECTRIFICATION

It is evident that the farm load and demand diversity are, and will continue to be, of such uncertain nature as to make circuit computation difficult. But this is the time to start the study of the characteristics of this diversity and to continue it. The present cost of the numerous demand meters which would be required makes such a study practically impossible. It is necessary to resort to statistical interpretation, and very little has been done even by statisticizing. The great accuracy of the present meters, which were developed for different purposes would not be required. If a simple, cheap, recording ammeter were to be brought out, there would be a quantity market for it.

Our present methods of testing grounds are cumbersome, and the testing equipment is too expensive. Here too the great accuracy for which the various instruments were designed is not required. With lower accuracy it should be possible to develop simple low-cost instruments for quantity production, so that each farmer who has a worth-while electrical installation could himself periodically test not only all his electric circuit grounds, but also all his lightning rod grounds. Simpler methods of attaching the testing instruments to the circuits also are required. There will be very little testing if the present procedure is to be continued, which makes it necessary in each case to dig up the soil at each ground rod, disconnect the ground lead from the rod, connect the instruments to the rod, disconnect it after the test, reconnect the ground lead to the rod, and then refill the soil.

The crystallization of problems and their solution are essential if the farmer is to have eventually the degree of continuity of service which the character of the load calls for or will call for in the future when more items of electric equipment for farming are made available. In fact, the speed with which many new uses of electric service will be introduced on the farm will depend to a great extent on the speed with which many engineering problems will be stated and solved.

Line Equations. Most of the primary circuits in rural areas are single-phase multigrounded 60-cycle 7,200-volt phase-to-ground. There is a main conductor and a neutral conductor. A multiplicity of parallel grounds exist along the line, primary, and secondary. This is one of the most complex circuits in electrical engineering. The question as to why this specific circuit was selected instead of a delta circuit would be beside the point at this time, because there are already hundreds of thousands of miles of such circuits and the time has definitely arrived to establish a mathematical foundation for them. After consulting many outstanding authorities, to the best of the author's present knowledge, the general differential equation for the multigrounded single-phase circuit has not been set up yet. After it is eventually set up, it no doubt will be of a series character with numerous variables, and very likely it will not be possible to integrate it generally. It very likely will become necessary to assume some variables as constants for different purposes and establish a different integration for each purpose.

The mathematical study is now under way, and the indications are that the basic differential equation soon will be available. Until it is available, problems of short circuit, voltage regulation, hazards brought about by voltage gradients on the surface of the soil, and similar problems cannot be solved to the full satisfaction of electrical engineering.

Grounding Practices. What goes on in the soil in the proximity of such a circuit? Very few test data or analytical data are available. The answer will not be at hand until many more tests are made and interpreted in the light of the basic formula yet to be set up. It is known that the circuit in the ground does not flow in the direction of the line from ground rod to ground rod. Tests show that the voltage distribution in the soil is nearly uniform in each direction from each ground rod. It is evident that soil capacitance will have to be given consideration in addition to soil resistance. Observations made so far indicate that the voltage gradient on the surface of the soil can be modified considerably with multiple grounds of various designs. But the available data are inadequate as a foundation for definite designs in definite cases. It is evident that a great amount of testing superimposed on mathematical analysis will be required before a definite engineering foundation is available for the solution of many problems related to grounding practices.

This naturally leads to the question of the ground-return line, a single-phase circuit made up of one wire, the earth forming the return. Two types of hazards are mentioned in connection with the ground-return system. The first is the possibility of a break in the conductor which runs down the pole to the ground. The second is the possibility of dangerous voltages on the surface of the soil. It is evident from the foregoing remarks that no definite statements of a quantitative nature can be made at this time which would serve as a guide for those who are considering the use of such circuits. Neither is there sufficient evidence to prove or disprove that there are real hazards, what their degrees are, and how to overcome them.

It is to be noted that the National Electric Safety Code states that in urban areas a ground return "shall not be used" but in rural areas it is "not recommended." However, a responsibility is involved in recommending it because in case of a jury trial for criminal negligence relating to an accident, the recommendation of the National Electric Safety Code no doubt would carry considerable weight.

Analytically the ground return circuit is a special case of the general multigrounded circuit. Once the formula for the general circuit is available, the ground return circuit can be developed by making the neutral impedance equal infinity.

It is evident from this discussion that the least that can be done is to provide the best possible grounds everywhere and to inspect and test the grounds periodically, first to make sure that they are intact, and second to accumulate as much data as possible on the electrical characteristics of the specific soil.

Transformers. What specific engineering problems are implied in the little distribution transformer used on rural circuits? Surprising as it may seem, there are numerous complex problems. The sizes now used are those originally determined for urban purposes. The weight is important because of the handling difficulties in farm areas. Numerous accessories have been added to the little transformer, such as lightning arresters, gaps, and cutouts, which make it resemble a Christmas tree. A great deal of competent design study still is called for before reasonably satisfactory arrangement will be had.

It is essential that manufacturers are made to realize that it is more important for a rural transformer to have a satisfactory telephone influence factor than it is for an urban transformer. This also applies as well to small generators in isolated areas. The cost of the remedy is less than the cost of the investigation. It is gratifying to report that most manufacturers appreciate this problem and are doing their best to reduce harmonic troubles.

One of the most important features is the need for low core losses. An urban transformer may have a diversity of loads with a reasonably good over-all load factor. A rural transformer generally has only one consumer. The copper loss load factor may be as low as 15 or 20 per cent, whereas the core loss load factor is always 100 per cent. There are cases where the billed kilowatthours are less than the core loss kilowatthours which are not billed.

Great strides already have been made in rural transformer design. But considering the fact that the cost of core losses on rural distribution transformers amounts to several million dollars per annum, further reductions definitely are called for. It is reasonable to assume that they will be forthcoming.

Voltage regulation problems on rural circuits are not vastly different from those on any circuit. They are only more aggravating, first because the rural circuits extend comparatively great distances from the source, and second because line investment must be kept to a minimum.

As already mentioned, the solution of the problem of voltage regulation is first of all waiting for the setting up of the basic circuit formula. Inexpensive low-capacity regulators with small steps are needed for regulating long branch lines. The rapid changes in load characteristics which may be expected in the near future would seem to make it imperative for manufacturers to explore the possibility of inexpensive secondary regulators. Perhaps some such device eventually will be incorporated in the distribution transformer.

The rapid growth of motor power on rural systems indicates an eventual need for low cost capacitor installations to switch on and off automatically with load. Series capacitors no doubt would solve many a problem, but a competent system of protection for such capacitors still remains to be developed.

Protection. It was mentioned before that the absence of a diversity of relays and electrically operated circuit breakers makes circuit control in rural area difficult. In addition, the small circuit breaker available for sectionalizing primary rural circuits has to be automatic reclosing. And yet, the performance of this little circuit breaker is nothing short of being miraculous. One case has been reported in which the circuit breaker operated up to 93 times during a fault.

This is quite an accomplishment for a little circuit breaker.

The same system which installed 60 circuit breakers in 1942 reports:

> "Average number of operations per year per circuit breaker 12.12 with an average of 0.25 lockouts per month. The total operating expense saved by each circuit breaker per year is estimated as over $26.00. This is based on straight time pay, even though actually about 50 per cent of the outages had to be taken care of by overtime at time and a half. The cost of fuse replacements is offset by the cost of maintaining the circuit breaker."

However, even this investment is too high for minor primary tap lines. Two manufacturers therefore now are bringing out still smaller circuit breakers at considerably lower cost because this small circuit breaker requires practically no rupturing capacity. One manufacturer, for instance, furnishes the following description:

> "The sectionalizer is designed so that its contacts do not open during the time that a short circuit exists on the system. The actual clearing of line faults and interrupting of short-circuit current is performed by a backup recloser. The sectionalizer operates to disconnect the branch line only after one, two, or three operations of the backup recloser have failed to clear the line fault.
>
> "When a permanent line fault occurs beyond a sectionalizer which is backed up by a recloser, the short-circuit current flowing through the sectionalizer will prepare it for an opening operation. The short-circuit current which also flows through the recloser will

cause it to operate in an attempt to clear the fault. During the time which the recloser is open, the sectionalizer moves forward one position toward the opening of the contacts. The second operation of the recloser again prepares the sectionalizer for an opening operation and during the time that the recloser is open the sectionalizer again moves forward another position toward opening. After the third operation of the recloser, the contacts of the sectionalizer are opened during the time that the recloser is open. In this way the faulted branch line is disconnected and when the recloser energizes the system after the third operation, the fault has been removed, allowing service to be continued to the balance of the system.

"The sectionalizer may be adjusted to open on a permanent line fault after one, two, or three operations of the backup recloser. Inasmuch as the sectionalizer opens its contacts only during the no voltage period while the backup recloser is open, the sectionalizer is not required to interrupt short-circuit current. Consequently, there is no appreciable wear of the sectionalizer contacts or contamination of the insulating oil."

Even for the primary and secondary sides of the little distribution transformer manufacturers have been at work developing automatic devices to replace fuses. The type of transformer with internal primary fuse and internal secondary circuit breaker has become very popular. One manufacturer recently placed on the market a "fuseless cutout." This device is said to produce a dead short circuit to ground on the primary side when a heavy overload occurs on the secondary side or within the transformer, resulting perhaps in a heavy arc on the primary side. The main reclosing circuit breaker then trips. As soon as this happens the arc is extinguished. When the main reclosing circuit breaker recloses, the arc is out; the individual faulty transformer is disconnected; the reclosing circuit breaker remains closed; and the whole system, except for one consumer, again has service.

One reason against the latter two types is that every time there is a fault on the tap line or on the individual transformer, the main sectionalizing circuit breaker will open for a short period thus causing short outages of service to the entire area.

Anyone who is familiar with the history of switchgear knows that no item of electric equipment has been undergoing such a continuous process of change and improvement as has the circuit breaker. No circuit breaker design ever is finished. The need for major and minor improvements continually is revealed by continuous co-operation of manufacturer and operating man. No one therefore needs to be unduly disturbed if operating experience calls and will continue to call for improvements in the design of the rural sectionalizing circuit breaker which already meets unprecedented demands. It is certain that as the need for improvement is revealed manufacturers will introduce them.

The early types of reclosers used on rural circuits had a very short opening time delay. Consequently, in many cases when the recloser was closed back in on the load for re-energization purposes, the inrush current retripped the recloser. In many cases the recloser had to be by-passed temporarily in order to pick up the load.

Some later designs have greater opening time delay, overcoming pickup difficulty to some extent. However, the exact shape or characteristic of the inrush current as it varies with time is not yet sufficiently known. Moreover, the rapid increase in the use of motors on the farm promises to make the problem much more serious.

Tests now are being carried on to determine the shape of the inrush current time curve and to predict the ultimate shape with the load growth. Preliminary tests on one section of rural line indicate an inrush current of less than 200 per cent of the normal peak after an outage of a few seconds. After an outage of one hour the inrush current was 400 per cent of the normal peak. But in all cases the inrush currents decayed to roughly one-third of their initial values in the first two seconds.

Small rural generating plants run fewer machines at light load than at full load. The full load current at peak, therefore, may be more than the fault current during off-peak hours. The power factor of the load current is not vastly different from that of the fault current. Inexpensive devices are needed that will distinguish between load and fault currents, and which could be applied to pole-mounted reclosers.

In some cases of transformer failures the line sectionalizing devices may operate to lock out the lines before the transformer fuses blow. The transformer then may be very difficult to find. There seems to be a vast difference in characteristics of internal fuses furnished by different manufacturers. There is a need for standardization of internal fuses and development of recloser and fuse characteristics to co-ordinate more properly.

Fault Locating. The problem of fault locating is as old as the electric circuit itself. Aggravating as a long delay in locating a fault may be in urban areas, it is even more aggravating in rural areas. And again the problem is aggravated by the imperative demand to do the job at low cost.

Rural distribution systems extend into remote areas which frequently are served inadequately with telephone facilities or have no telephone service at all. Outages in such areas may be prolonged because of lack of communication with the power maintenance office. There are cases on record in which the maintenance office was notified of outages by postal card and letter. Needless to say, such loads as milking machines, coolers, chick brooders, and water pumps make prolonged outages intolerable.

A carrier current outage recorder was manufactured experimentally and was undergoing field tests at the outbreak of the war. It consisted of a small low-cost carrier current transmitter located at each important sectionalizing point and an associated receiver located at the maintenance office. When an outage occurred a coded impulse from the appropriate transmitter was sent to the receiver, which activated a punch-type paper strip recorder and time stamp. Thus, the location and time of the outage were recorded immediately. Provisions were made for another operation of the recorder when service was restored so that a complete record of the outage could be maintained.

Several schemes which offer the possibility of being simpler and more reliable than the original one are being considered now. One of these schemes may make use of the radar pulse technique for detecting circuit irregularities and discontinuities. Another scheme may make use of the change in circuit impedance when an outage occurs.

It appears today that some competent means for reporting and recording outages automatically will be solved in the not too distant future.

Inductive Co-ordination. Mention already has been made of the fact that the main problem of inductive co-ordination in rural areas is the cost of investigation. With the great amount of research and development over many years and the unusually high degree of co-operation by power system engineers and communications engineers, there is as yet no cut and dried method either for locating the source of trouble or for designing the remedy. Each case is still practically an individual research job, and each remedy still has to be practically a tailor-made job. A complete visualization of the simultaneous functioning of an interconnected power system is called for, superimposed on a visualization of the functioning of the communications systems, in addition to a familiarity with the functioning of each part of each system. Ability for such a visualization cannot be acquired in a day.

With the exception of radio, full co-operation prevails between the engineers of power systems and those of communication systems, so that neither side is called upon to carry alone the burden of the investigation and the design and installation of the remedy. Power systems and communication systems both find it advisable to have specially trained engineers available. These engineers on both sides generally communicate with each other and tackle the job jointly. Not only do the engineers on both sides co-operate after a case of interference actually is reported, they also consult with each other when a power system or a communication system is being designed and thus prevent in advance as much as possible the appearance of interference. Research laboratories and manufacturers of power and communication equipment likewise render their services and co-operation. When a case of radio interference is reported, the whole burden of locating the source of trouble and designing and installing the remedy has to be carried by the power system. It is hoped that it will be possible soon to establish between the engineers of power systems and those engaged in broadcasting, radio research, and radio manufacturing the same degree of co-operation that now prevails in other fields of communication.

There is now a great need for a simple, practical, and inexpensive radio interference locating instrument, specifically for rural areas. There is definitely a quantity market for such an instrument.

Communication. In addition to the previously referred to possible use of carrier for the automatic recording of outages, carrier recently has been tried out on some rural power systems for communication purposes for power system maintenance. Here too the difference between carrier on high voltage lines and carrier on rural lines is principally one of permissible cost. Some interesting and promising developments of two-way radio as an auxiliary to maintain the rural power system are taking place now. Possibly, leased radio channels furnished by telephone systems will be the best answer, just as leased telephone wires were found by many power systems to offer advantages over private telephone circuits on the transmission towers or on separate poles.

RURAL COMMUNICATIONS

All of this relates only to communication problems for the power system itself and not to the problem of communication for the farmer. Particularly in the case of carrier there has been some confusion of the two, and it is important to establish the distinction. Recently an unprecedented demand for telephone service developed among farmers throughout the country. This probably was brought about partly by the enormous increase in the use of mechanical and electric equipment on the farm. The challenge was taken up and is being attacked rigorously from three angles:

1. There is a great activity in the extension of direct wire comunication to farms.
2. Intensive studies are being made and experiments carried on in the joint wire use of power poles for telephone and telephone poles for power.
3. Intensive experiments are being carried on in the joint use of carrier telephone on power lines to render telephone service to farmers who have electric power service.

In connection with carrier it is important to mention that there is a great difference between the incidental use of a carrier telephone by a lineman to talk to his headquarters and the continuous use of telephone service by a domestic or commercial telephone subscriber. Several years of research at great cost have been devoted to the latter problem, both in the laboratory and in the field, before the first experimental instruments were installed in farm homes. Here again, the cost is of extreme importance. One of the bottlenecks of cost was the coupling capacitor. For a long time the cost appeared to be prohibitive, until a progressive American manufacturer developed a capacitor for a 7,200-volt line, with a dry impulse flashover of about 200 kv and at a cost of around $10. It is reasonable to say that without this development carrier telephones in quantity would not be an immediate prospect for the American farmer. They are definitely so now.

The Industrialization of Mexico

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For years, the average Mexican, and most especially the Mexican farmer, has been existing on an economic level which does not include an adequate supply of even the barest necessities. The Mexican Government, in its desire to raise the standard of living, realizes that the only hope for a country whose agricultural lands already are overpopulated lies in industrialization. For equipment, for technical information, for investment, Mexico looks to the United States with the assurance that, rather than close the market to foreign products, the fostering of Mexican industry, by increasing the economic capacity of the people, will create an even greater demand for American-made goods.

GEOGRAPHICALLY, Mexico is bounded on the north by the United States; on the south by the Pacific Ocean, the Republic of Guatemala, and the Belice Territory; on the east by the Gulf of Mexico; and on the west by the Pacific Ocean. The country has a total perimeter of 13,580 kilometers (8,315 miles) as far as coasts and borders are concerned, and a total area of 1,963,890 square kilometers (738,259 square miles).

The Mexican territory is crossed by abrupt mountain ranges with a high plateau comprising the central part of the country. Its climate varies from tropical in the south to semitropical and dry in the north.

The total population of Mexico in 1940, according to the census of that year, was 19,655,552 inhabitants, and subsequent calculations show that it increased to 21,672,733 by December 1945. Of this total, approximately half is illiterate, and only 25 per cent is active economically. About 70 per cent of the population lives in rural areas and depends upon agriculture for a living. Less than 5 per cent is employed in industry, and only about 1.5 per cent serves the national government. The total number of Mexican professional workers—engineers, physicians, lawyers, and others—at present hardly totals 100,000 persons.

Living conditions in Mexico are poor. It is sufficient to say that 88 per cent of the homes are adobe houses or are made of wood or similar materials. Only 12 per cent of inhabited buildings are of stone or brick. Nearly 50 per cent of the population dwells in hovels, huts, or barracks.

The clothing situation is equally deplorable as nearly 80 per cent of the population wears inadequate clothing.

In addition, food is insufficient and poor and the purchasing power is not high enough to improve it. This factor is evident in Mexico's mortality and disease rate.

Concerning drinking water, only 12 per cent of the population is served by the pipe system, 28 per cent must have recourse to the so-called "semipotable" source, and the remaining 60 per cent is deprived wholly of water supply for domestic purposes. As to drainage service, only 7.4 per cent of dwelling places have access to it. Electric service likewise is insufficient, not being available to more than 20 per cent of the population.

The Mexican system of transportation, even in the light of the foregoing statistics, is definitely poor. The national highway network amounts to scarcely more than 8,000 kilometers (about 5,000 miles) of paved roads while railway lines run short of 24,000 kilometers (about 15,000 miles).

The value of agricultural production in Mexico per year is estimated at 650,000,000 pesos (approximately $130,000,000); the value of the mineral–metallurgic production reaches about 800,000,000 pesos (approximately $160,000,000); the value of industrial production is very near 2,000,000,000 pesos (approximately $400,000,000). Mexico's foreign trade has a balance of about 1,000,000,000 pesos (about $200,000,000) in exports, and 750,000,000 pesos (about $150,000,000) in imports.

Mexican wages vary enormously as can be seen from the following figures. It is estimated that a man working in the country has at his disposal no more than 200 pesos (approximately $40) per year after paying for food and shelter; the average salary of one working in industrial concerns amounts to something more than 1,500 pesos (approximately $300) per year. It is estimated further that a family composed of four members has a weekly income of something less than 30 pesos (about $6).

Mexico's economic system has been one of those commonly referred to as "semicolonial." For centuries she has contributed to the enrichment of the world through the mining of her metals, yet she has never shared in her exported resources. As far as her economy is concerned, however, Mexico is ready to exchange her position as a leading raw-material provider for that of

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Table I. Summarized Data on Mexico's Mineral-Metallurgic Production and Exportation During the Period 1931–1944

Products	Total Output (Tons)	Total Exportation (Tons)*
Gold	316.627	226.741
Silver	34,151.148	23,539.937
Copper	603,211	460,696
Lead	2,720,996	2,016,484
Zinc	2,015,239	1,267,668
Antimony	109,956	63,347
Arsenic	144,467	83,180
Cadmium	9,188	6,298
Coal	13,308,842	
Tin	5,258	3,912
Graphite	143,331	80,140
Iron (pig)	1,177,153	52,057 (minerals)
Manganese	73,803	663
Mercury	6,022	2,752
Molybdenum	11,520	6,447
Tungsten	1,077	526
Vanadium	448 (until 1941)	447

* These exportation data include only up until 1941; data for later years were kept secret during the war and have not been published as yet.

a producer and exporter of finished products and processed materials. The Mexican Government and people alike realize and understand this ambition and feel that nothing ever will stop the progress of a nation that tries to develop within itself what others have tried to snatch from their neighbors.

NATURAL RESOURCES

Mexico long has been noted for her rich natural resources. The truth is that with the exception of five or six products, the existence and abundance of which have been demonstrated completely, no accurate knowledge is available on what can be mined from the Mexican subsoil.

As far as mineral resources are concerned, Mexico produces gold, silver, copper, lead, zinc, antimony, arsenic, bismuth, cadmium, graphite, iron, manganese, mercury, molybdenum, tungsten, and vanadium. Aluminum, cobalt, strontium, platinum, uranium, and other radioactive minerals, also are known to be present, although they have not been exploited regularly.

Of the natural fuels, petroleum is plentiful in Mexico and certainly the mineral coal resources are large enough to meet any possible demands. There is also a great abundance of lumber and Mexican fields are generally fertile. Hydraulic resources are poor, however. No less than 60 per cent of the whole territory must be considered arid land. For some representative figures on Mexico's mineral-metallurgic production and exportation see Table I.

The value of mineral-metallurgic production exceeds 7,000,000,000 pesos (approximately $1,400,000,000) and this production, as may be seen from Table I, has been exported almost wholly to foreign markets. (Mexico's standing in the production of some of the products is shown in comparison with the rest of the world in Table II.)

No doubt the present economic situation of the country would be different if the leading mined resources were not exported in full. The fact that they are exported accounts for Mexico's inability to depend on any of the metals for her own use. In spite of the fact that she is one of the leading producers of such minerals as silver, copper, lead, zinc, antimony, arsenic, and cadmium, Mexico must obtain these products from foreign markets which she previously has provided.

It is probable that industrialization of Mexico would result in a more rapid development and better coordination as far as the exploitation of her natural resources is concerned. As a matter of fact, many of the latter, which at present do not invite capital because their exploitation is exceedingly expensive for exportation purposes, certainly would offer better opportunities for investment if they were to be employed as raw materials on behalf of Mexican industry. Increased industrialization is, in turn, Mexico's only hope of improving and raising the standard of living of her people.

AGRICULTURE NOT ENOUGH

There are special reasons why Mexico's agricultural problem should be treated separately. It has been customary to state that the country is essentially agricultural, and this opinion is based on the consideration that more than two thirds of Mexico's population are devoted to farming activities. But this latter fact does not substantiate the statement that Mexico is primarily an agricultural country; it shows instead that Mexico's farming lands are overpopulated, and this partially accounts for the many and serious problems Mexico has to face in this respect.

The living standard of the Mexican farmer hardly could be lower than it is at present. The average production per worker is low and so is the average production per cultivated acre. As noted previously, it is estimated that the money each farmer can accrue scarcely amounts to 200 pesos a year after allowing for food and shelter. It is easy to understand that under emergency conditions and with high prices, the life of the farmer must be, of necessity, miserable and cruel.

This situation is the result of various causes among which must be mentioned the exhaustion of the lands owing to the century-old system of monocultivation, insufficient rain and inadequate irrigation, lack of technique and fertilizers, and the absence of machinery and agricultural implements. All of these factors prolong indefinitely the low efficiency of the country and its men and are responsible for the fact that present agricultural exploitation cannot meet the food needs of the Mexican people.

The hydraulic resources of Mexico would suffice to irrigate 5,000,000 hectares (12,350,000 acres) throughout the great extension of arid and semiarid zones that make up the Mexican territory. Moreover, in humid and tropical zones, the amount of rainfall would permit the cultivation of 1,500,000 hectares (3,705,000 acres) under adequate sanitary conditions.

It is of interest to note that from the time of the Aztecs until 1910 approximately only 700,000 hectares (1,729,000 acres) were given the benefit of irrigation, while from 1926 until the end of 1946 an additional 900,000 hectares (2,223,000 acres) will be irrigated. This proves that 20 years of constructive work can accomplish more, as far as irrigation is concerned, than four centuries. It also shows the great effort that has been made and that the government is fostering in order to improve agriculture and, consequently, the status of the Mexican farmer. The appropriations for irrigation works, a better technique in agricultural exploitation, the introduction of machinery in the latter, and so forth, have been on the increase year after year and they amount at present to 190,000,000 pesos (about $40,000,000), something more than 15 per cent of the national budget. This, in due proportion, must be regarded as an unprecedented investment by any country of the world. However, in spite of such great efforts, the amounts of money invested still are insufficient to meet the present needs, and, above all, to attain a just rise in the living standard of the Mexican farmer.

The progress that has been attained proves that the country cannot be merely agricultural, that the requirements of modern life cannot be dismissed by improving agriculture with a view toward facilitating and guaranteeing adequate food for the population. The great needs and requirements of modern life prove that no man can satisfy his spiritual, social, and bodily needs through the sole increase of agricultural exploitation. Civilization offers many ways to satisfy these needs but the enjoyment of such benefits is attained only if natural resources are made use of by means of a manifold economic production, and that means industrialization of the country. The Mexican people cannot, and do not, want to continue living under social and economic conditions such as they have been subject to thus far. Industrialization and progress no longer can remain a dream. They must become a fact in the interest of human welfare.

NEED FOR INDUSTRIALIZATION

What has been said thus far might seem to obviate any further emphasis on the urgent need for Mexican industrialization. However, the very agricultural situation of the country, which has its greatest problem in its excessive agricultural population, begs for the immediate introduction of machinery in national agriculture, points to the need for reasonable farming methods, and demands radical transformation of traditional farming systems through the use of fertilizers.

The need for the application of machinery, reasonable farming methods, modern technique, and the use of fertilizers in themselves are sufficiently weighty reasons to advocate industrialization because all those factors, as a whole, make it even more urgent to displace great numbers of farmers to other activities and working centers.

Table II. Mexico's Place in the World's Mineral-Metallurgic Production*

Product	Mexico's Place	First Place	Last Place
Gold	8	Transvaal	Czechoslovakia (44)
Silver	1	Mexico	Australia (47)
Copper	8	United States	France (26)
Lead	3	United States	Turkey (26)
Zinc	6	United States	Yugoslavia (18)
Antimony	2	China	British Borneo (26)
Arsenic	4	United States	Greece (15)
Bismuth	Mexico produces 1/8 of the world's production	United States	
Cadmium	2	United States	Russia (12)
Tin	17	British Malaya	United States (18)
Graphite	7	Chosen (Korea)	Indo China (24)
Iron	26	United States	Belgian Congo (29)
Manganese	23	Russia	New Zealand (37)
Mercury	5	Italy	Chosen (Korea) (16)
Molybdenum	3	United States	Canada (13)
Tungsten	20	China	Brazil (30)
Vanadium	5	Peru	Mexico (5)

* These data include only up until 1939; war prevented the publication of data for later years.

The task of readjusting the excessive farming population, such as created by the natural development and efficient exploitation of agriculture, will become even more complicated with the normal increase in population, now estimated at 500,000 per year, which probably will become even greater with the decrease in the mortality rate. The task will become more difficult with the increasing rate of the natural migratory current from Europe to America, still more with the inevitable repatriation of some part of the 2,000,000 Mexicans now employed in the United States in temporary or permanent occupations. Such people cannot be placed except in factories, shops, or industries.

The efforts of the Mexican Government to raise the people's cultural standard will prove to be an important factor in the country's uplifting. The present campaign binding every Mexican citizen who can read and write to teach one illiterate person has led to new needs and aspirations to a new life. This is another factor which will bring about a great migration from the country to the city. Immigrants will demand the satisfaction of their bodily and intellectual needs as well as social needs and these in turn will mean an enormous demand for more and better food, clothes, homes, schools, libraries, and recreation centers, as well as for the production of countless goods which can be acquired only in proportion to the economic capacity of those in need of them.

The mechanization of the country will give rise to the establishment of factories to produce the necessary machinery; the introduction of fertilizers will give rise to the industries needed to prepare them; the need for more and better clothes will transform the textile industry; the abundance of food supplies will lead to the construction of refrigerating, packing, and cold storage plants; the building of new and better homes will foster the cement industry, as well as the iron and timber industries; means of transportation will have to be improved in order to handle the products; the improvement of living conditions will necessitate a supply of great amounts of fuel; the use made of certain mineral resources will bring about the construction of new factories. All this will require the establishment of auxiliary industries, the output of which is to complement a way of life the Mexican people have not yet experienced.

In order to satisfy the needs of industry, home, and commerce, more and more sources of power will be necessary, and consequently the electrical industry must make plans in advance for this future we all anticipate now.

The conditions prevailing in Mexico, such as have been described, reveal the existence of an economic situation which certainly places Mexico's inhabitants on one of the lowest standards of living. This is true especially of those living in the rural areas. For example, in Mexico the consumption of iron and steel is 10 kilograms (22 pounds) per head, while in the United States this consumption is 750 kilograms (1,560 pounds); in Mexico the number of automobiles is 1 per each 100 inhabitants, while in the United States there is 1 automobile to every 4 inhabitants; in Mexico there is an installed capacity of 38 watts for every inhabitant, in the United States the corresponding capacity amounts to 384 watts; the annual consumption of electric energy in Mexico is 156 kilowatthours for every inhabitant, while in the United States it approximates 2,000 kilowatthours.

In citing the foregoing statistics we do not pretend in the least to place on the same level Mexico's power of consumption with that of the United States. We only wish to show by comparison the existing need to raise the Mexican standard of living gradually so that the country may come nearer to such conditions as prevail in countries which have less abundant resources but are better off because of industrialization.

CONDITIONS ESSENTIAL FOR INDUSTRIALIZATION

The first condition for Mexico's industrialization is the immediate provision for the natural exodus of population from the country to the city. This provision also should include possible immigrants from Europe—such as Mexico can shelter—as well as Mexicans returning from abroad, who otherwise may be likely to create a social problem which it might be difficult to solve.

The phenomenon of human absorption from the country to the city must be conditioned to rural mechanization in such a manner that the process thereof shall not entail the danger that might be represented by the sudden enlargement of city centers with a population which is not able to produce but which must be fed. Many complicated problems of a technical character must be solved in order to prepare, with proper foresight, the new centers of occupation, and so it is advisable to make a methodical choice of men to solve these problems. This need for trained personnel will require new schools and institutions to adapt and enable such men to carry on such mechanical and technical services as may be required by the various industrialization stages. A continuous and persistent renovation of every social and legal principal now obsolete is most urgent as such principles might hamper and hinder the technical evolution now imposing itself upon Mexico.

All this must lead to the employment of an ever-increasing number of workers, with higher salaries and a higher standard of living, to enable persons in every walk of life (farmers included) to consume manufactured articles now out of their reach. The amount of progress to be attained justifies the prediction that Mexican industry for many years will find its greatest market in its own territory.

Another condition for efficient industrialization concerns the constant modernization and enlargement of factories in order to lower the cost of production and consequently insure the consumption of products among such population centers as now are unable economically to acquire the same products. At this point we should state that we believe that it would not be either logical or economical to try to establish industries that might compete with foreign industries, which are enormous. In this respect, it is to be emphasized that the great industrial countries must regard Mexico's industrialization as a factor favoring their own markets. They must not fear that Mexico would repay their help and co-operation with unlawful, harmful competition. Surely Mexico realizes her inferiority in regard to great industrial enterprises which have been established, especially in the United States. On the other hand, the gradual industrialization that Mexico is striving for will enable the country to become, day after day, a better buyer of foreign products. As we become economically stronger, we will be able to acquire (which we have not done so far) that which we are not able to produce. Paradoxic as it may appear, the fostering of agriculture and industry will lead to our becoming better and better clients of industrialized countries.

The Mexican Government and people even now are concerned with establishing all such conditions as may guarantee a safe and orderly economic development. To this end the potentialities of areas suitable for the development of industrial centers must be studied and foreseen, and such areas must be provided with such basic elements as may make them attractive. Among such elements must be included drinking water and drainage services, communications, electrical services, and adequate plans for habitation. All of this must be carried out taking into consideration not only local conditions but also those affecting the industries themselves. Here, consideration must be given to such factors as raw material transportation, and the moving of finished products. Special attention is to be paid to those industries which are likely to improve the conditions of the people most rapidly. No doubt the food industry and the textile industry must share first place.

Among the conditions for the development of the Mexican industry is that ensuring the permanence of industrial enterprises. Such a condition can be attained only when the need for products means a need for a permanent market. Undoubtedly, the good quality of the products is a contributing factor, and such quality must be controlled in compliance with adequate standards. A like condition of permanence in industry is one establishing co-ordination and mutual help among the industries founded, so that they all concur to shape and confirm the welfare of the nation.

The direction of industry by principles of advanced technique must be a factor of great importance, for it is only on a technical basis that the necessary co-ordination can be established between need and satisfaction.

A last condition to be mentioned is one which will provide for harmonious co-operation between capital and labor, between worker and employer. To this purpose laws must be passed so that the interests of these two important factors may be combined to serve best the high aims of the Mexican people.

The engineer will be of the greatest importance in the preparation, direction, and realization of every plan related to industrial development. Even in the difficult task of harmonizing capital and labor and of laying down the rules for capital and labor relations, we believe that the engineer can help greatly, since no one but the engineer, abiding as he does between the worker and the employer, can contribute more toward smoothing the difficulties arising between those two factors bound to be brothers and yet so often enemies. The abstention of the engineer from work and capital conflicts cannot be justified, as it is a fact that no one is better qualified than he to harmonize the leading factors of production.

Such conditions as have been enumerated, which are necessary for the industrialization of Mexico, are now on the way to realization. The Mexican Government earnestly is preparing the basic elements needed so that private initiative may find conditions for easy development. This is shown in the continuous efforts made in irrigation, electrification, roads, health, drinking water supplies, building of laboratories, industrial legislation, and so forth. It is to be expected that in coming years such efforts will be improved and that soon such conditions will be established as may transform the country by means of a well-balanced agricultural production, as well as by mining and industry, through the co-operation of both private and government initiative.

INDUSTRIAL PROJECTS UNDER WAY

As a result of Mexico's present needs, and as a consequence of the government's disposition to favor industrial development, it is highly encouraging to state that from 1940 until the present more than 200 industries—requiring capital of more than 400,000,000 pesos (something more than $80,000,000)—have been established. These industries produce or will produce electric and iron articles, chemical products, food, and wooden articles, as well as such products as building materials, cement, and ceramic and glass articles. Among the factories now under construction, is one being built by Industria Electrica de Mexico, S. A., which will produce electric machinery and apparatus with designs and patents of the Westinghouse Electric Corporation.

In the city of Monclova, Coahuila, Altos Hornos de Mexico, S. A., has established a metallurgical industry producing steel plates and sheets, tubes, and other iron products, which will contribute to the flourishing of other Mexican industries.

Another industrial concern deserving of recognition is that which, under the name Celanesa Mexicana, S. A., will produce such artificial fibers as rayon, cellulose, and acetate.

The cement industry has become particularly important during the last few years, as several factories have been constructed and others are on the point of starting production.

Shops and foundries are increasing in number and siderurgical industry is expanding rapidly in order to meet the country's needs. The same thing may be said about the textile and food industries.

The electrical industry deserves special mention. This industry (as it is pointed out in another article prepared by the Mexico Section)[1] will concentrate as much as 500,000,000 pesos (about $100,000,000) in investments during the next three years. In this time, with the collaboration of government and private capital, an installed electric capacity of more than 400,000 kw can be added to that already in existence.

If the present rate of construction and development is kept constant it is safe to state that within the short period of ten years, Mexican industry will become a decisive factor in the country's economy. In this manner, realization of Mexico's efforts to improve economic conditions, which have been so poor for so many years, finally will begin.

SUPPORT NEEDED FROM THE UNITED STATES

We wish to emphasize the fact that Mexico's industrialization not only will not affect adversely the market of industrialized nations, but, on the contrary, it will be to the advantage of such nations that this industrialization be carried out in a rapid and efficient manner since Mexico thus will be enabled to acquire foreign products in greater amounts than heretofore. We feel that it is the United States which will be benefited directly by our industrialization. Great quantities of machinery and materials are to be acquired and it is logical to assume that since the United States has a powerful technical influence upon Mexico's technique, such influence will be taken advantage of by employing American-made equipment on behalf of the good-neighbor policy.

Mexico is in special need of co-operation and help from the United States, on the basis of which she may not only acquire equipment and machinery but also technical advice that may be offered her either in the manner of services or through adequate publications. Also, our economic conditions sometimes will require special financial support and no doubt it will be to the interest of Americans to close deals that will benefit both countries mutually on the basis of the doctrines that related both nations during the war that has just been won.

We believe that the engineers of both nations, since the language of technique is universal, can and must do much to attain mutual understanding. The AIEE is, at present, the technical association which has contributed the largest share toward arousing a great interest in friendly relations, and we endorse the hope, expressed by Charles A. Powel, past president of the Institute, during his visit to Mexico in 1944, that the engineers of the world may form an association to discuss, on the basis of technique, the problems of every country.

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Electronics in Measurements

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Characteristics of electronic instruments such as extreme sensitivity, great amplification, and fully automatic operation permit measurements to be made which are not possible by any other means. Although it is in such applications that they find their greatest present use, with the production of components better suited than existing ones for heavy-duty industrial service electronic measuring devices should find greatly extended employment.

TO THE trained engineer as well as to the layman electronics* connotes something miraculous; it carries an air of the magical. And well it may. The eye of radar, which can "see" a single airplane more than a 100 miles away through total darkness, or the robot airplane (such as used at Bikini) equipped with an electronic automatic pilot and operated over a radio link, which can warm up its engines, speed down the runway, take to the air, fly over long distances and execute complicated maneuvers, and return to its base, all without a human being aboard, are truly miracles of the 20th century. In the field of measurements too, electronics can perform miracles. Electronic methods can accomplish measurements which are not possible by any other means. And yet it may surprise electronic engineers to know that measurement specialists have been slow and cautious to adopt electronic methods, and that these methods hardly have begun to invade the measurement field. Why?

In the first place electronic methods must compete with existing mechanical electric, hydraulic, and pneumatic methods. Unless electronics can do the job better or cheaper, the older, more orthodox methods will prevail. The electronic method must be superior to survive. Most of the basic physical quantities, such as length, mass, and time were measurable by highly accurate, highly reliable, and well-perfected methods long before the inception of electronics. What could be simpler and more reliable than a chemist's analytical balance, easily able to measure to an accuracy of one part per million? In the measurement of time a small and compact chronometer will measure to an accuracy of five seconds per month, or approximately two parts per million. A compensated pendulum clock will measure time reliably within one or two seconds per month, or better than 0.5 part per million. Such devices are highly perfected, easily obtainable, and give an accuracy seldom equalled in electrical measurements.

Many derived quantities similarly have been measurable easily and accurately long before the availability

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*Electronics should be defined because it is being used currently with rather different meanings. As used in this article electronics applies to any method or device employing vacuum tubes, those vacuum tubes including gas tubes and photoelectric tubes.

of electronics. It is hard to improve on the Bourdon spring for measurement of ordinary pressures. It is hard to improve on liquid-expansion or gas-expansion thermometers for measurement of ordinary temperatures, on thermoelectric pyrometers for measurement of medium-high temperatures, or on electrical resistance thermometers for measuring low temperatures. In these fields electronics has comparatively little to offer.

The same thing is true in the realm of many electric quantities. It is difficult to conceive of a mechanism more simple, more reliable, and more direct in operation than the permanent-magnet moving-coil system for measuring direct voltages and currents. Similarly, it is difficult to conceive any mechanism which could improve on the dynamometer system for measuring electric power. The dynamometer measuring element automatically takes into account varying voltages, varying phase positions, and even varying wave forms, and solves a calculus problem instantly, automatically, and accurately. Again, electronics has nothing to offer.

Thus it turns out that electronic methods often are adapted best to measurement of miscellaneous or special quantities such as light and sound intensity, color differences, composition of gases, pH (acidity or alkalinity of chemical solutions), solution concentration, and torque. It is in these special determinations, for which earlier methods of measurement had serious limitations, or for some of which there were no satisfactory quantitative measures at all, that electronics makes its greatest contribution.

ADVANTAGES OF ELECTRONIC METHODS

The characteristic advantages of electronic methods in the measurement field stem from the characteristics of vacuum tubes. Vacuum tubes can operate from virtually zero power input, and permit almost unlimited power amplification. Tubes can act as relays with zero inertia, unlimited speed of response, wide range, and smooth and stepless control. Gas-filled tubes can control very large currents instantly, smoothly, and over a wide range. They involve no moving parts, and require negligible power input. Electronic methods therefore are indicated for measurements of very small quantities, very rapidly changing quantities, very short time intervals, for measurements made without physical connection to the system under study, and for wide range, flexible, high-speed automatic controls.

Nonelectronic methods often require a human operator and manual manipulation. Electronic methods usually permit continuous automatic measurements, and hence can be adapted to automatic control. A typical example is the measurement of light intensity. With the usual photometer, operating on the inverse square law, the brightness of two fields must be matched visually by a human operator. Automatic operation is virtually impossible. With the light to be measured impinging on a photoelectric cell, instantaneous automatic measurement is possible. This automatic control possibility of electronic methods is due partly to the ability of the vacuum tube to respond to very small inputs, to amplify these values, and to act as a inertialess relay; partly to the ability of photoelectric cells to measure light intensities quantitatively; and partly to the ability of accessory devices to respond to many nonelectric quantities and convert them into quantitatively proportional electric impulses.

This last point is the key to the wide range of use of electronics. Many nonelectric quantities can be converted easily, accurately, and continuously into electric impulses which can be measured electronically. Examples are light intensity, color differences, sound level, vibration amplitude, acceleration, speed, torque, forces, and stresses (particularly very large or very small), pressure, vacuum (particularly very high vacua), and time interval.

Thus electronic methods can make some measurements better or faster or cheaper than they can be made by conventional devices. But in such applications, the electronic method still has to compete with simpler and better known systems of measurement. It is in those special fields, where electronics can make measurements that are not possible at all by nonelectronic means, that electronic methods are most valuable and where they make their greatest contribution.

SOME TYPICAL ELECTRONIC APPLICATIONS

It has been stated that electronics can make measurements not otherwise possible. Examples are so numerous that they crowd in from many different fields. For example, the speed of a tiny rotor revolving at 50,000 to 75,000 rpm in an ultracentrifuge widely used in biochemical investigations must be measured and controlled accurately. The rotor usually revolves without bearings, supported in a stream of air or a magnetic field. No physical contact with it is possible. Mechanical methods of speed measurement are out of the question. Even electromagnetic induction would cause intolerable drag. However, with a white spot painted on the rotor, a beam of light can be made to flash a reflection to a photoelectric cell every revolution, and the photoelectric cell output will contain a current pulse for every revolution. With an electronic frequency meter, the frequency of these impulses can be measured and the speed of the rotor determined with no physical contact. Without electronic tools, this measurement would be impossible.

Another obvious example is the measurement of wave shape, particularly at high frequency. Although magnetic oscillographs can show us the shape of a wave at ordinary power frequencies, there is no mechanical means by which we can study a wave recurring at the rate of a million cycles per second. However, in a cathode-ray oscilloscope the high-speed relay action of the vacuum tube, plus an inertialess beam of electrons, makes possible a measurement that could not be made by other methods.

A third example is the quantitative measurement of surface finish. It is commonplace to specify surface finishes in terms of irregularity in microinches (millionths of an inch). Surface analyzers are now common shop equipment. Such measurements might be possible, but very difficult, using microscopic techniques. With a piezoelectric crystal, an amplifier, and suitable integrating circuits, it is easy to measure the irregularity of a machined surface in millionths of an inch, and the measurement is accurate and reproducible. This application also suggests the possibility of electronics in measuring many small motions or displacements.

The atomic bomb supplies a strikingly different field of application. Certain ships at Bikini were fitted with Geiger-Muller counter tubes in housings on the bows, which fed through amplifiers to continuous ink recorders in the pilot house. The recorder plotted a continuous and permanent chart of the degree of radioactivity of the water into which the ship was moving at any instant, and gave automatic warning when dangerous radiologic levels were reached. This is another type of measurement that could not be made automatically without electronic means.

Electronics has given the Bessemer converter for steel making a new lease on life. In the Bessemer converter a complicated series of chemical reactions occur in such a short time that chemical analysis is not possible. The classic method of control was for the operator to watch the character of the flame streaming from the converter mouth, and note changes of color and brightness. This required great skill because "overblowing" for as little as one minute can ruin a heat of many tons of steel. Now a photoelectric cell aimed at the converter mouth takes note of flame brightness, and by means of appropriate filters takes note of flame color as well. Through an amplifier a recorder is actuated making a continuous and permanent record of the process, and showing the exact end point at which the blow should be stopped and the heat poured. With the rapidly changing flame conditions ordinary visual field-matching photometry is out of the question. This is but one specialized example of the continuous measurement of light or color through electronics.

A somewhat related, yet widely different type of optical measurement, is the analysis of gas mixtures, and particularly the detection of deleterious or poisonous gases, by measurement of absorption in the ultraviolet region. Here ordinary visual methods break down completely because the radiation used is invisible. Photographic methods would be possible, but slow and cumbersome. By splitting a beam of ultraviolet light, passing one half through a column of pure air and the other half through a column of contaminated air, measuring the brightness of the two invisible ultraviolet beams on two photoelectric cells, and then detecting the difference between the output of the two cells, it is easy to detect very minute quantities of some gases. The presence of carbon disulphide in the atmosphere of rayon plants, or mercury vapor around mercury boilers can be measured and recorded by this means, and can be made to sound an alarm when the contamination exceeds safe limits. The method is extremely sensitive, it being possible to detect less than one part of mercury vapor in 100 million parts of air!

There are many chemical operations that involve mixtures of relatively inert gases that cannot be separated chemically, and which have such similar boiling points that they cannot be separated by fractional distillation. Such mixtures are commonly encountered in the hydrocarbon gases processed in high-octane aviation gasoline manufacture, and in the manufacture of synthetic rubber. Such difficult mixtures are readily sorted out by the mass spectrometer. In that device individual molecules are electrically charged, subjected to combined electric and magnetic fields, and then their presence is detected by an ion collector. The apparatus can be adjusted to respond to any particular molecular weight, and as the adjustment is changed molecules of each characteristic weight can be identified as they appear at the collector. The production of the necessary fields requires electronic means, but it is in the ion collector where currents of a small fraction of a microampere are encountered that electronics converts a delicate laboratory device into a rugged production tool.

Even though highly perfected devices for measurement of temperature have been available for a long time, there are some fields of temperature measurement that are very difficult. In a modern high-speed, continuous hot-strip steel mill, it is necessary to know the temperature of the heated billets just before they enter the rolls. The billet is moving swiftly, there is no opportunity for mechanical contact, and not enough time for use of an optical pyrometer. But a photoelectric cell with suitable balancing and amplifying circuits can make the measurement instantly, and without any physical contact. It can give the operator a visual guide, a permanent record, and even sound an alarm and automatically divert a billet which is outside the desired temperature range. A correlated application is the measurement of the temperature of the molten steel bath in an open-hearth furnace. Extremely high temperatures (3,000 degrees Fahrenheit and above) rule out base metal thermocouples. Rough and violent operating conditions rule out fragile noble metal thermocouples. Smoke and flame in the atmosphere, and a slag coating over the metal surface, make optical pyrometry inaccurate. But a simple pipe carrying a stream of air can be inserted momentarily through the slag covering into the molten metal bath, and the brightness of the inside of the uncontaminated bubble can be measured instantly and accurately by a rugged photoelectric cell.

An entirely different field is that of the measurement of high vacua. Many methods of vacuum measurement have been developed, and the McLeod gauge is the accepted standard. The McLeod gauge, however, requires manual manipulation. In the operation of many kinetic vacuum systems, it is necessary to know the vacuum continuously, even though it is of the order of one billionth of an atmosphere. Continuous measurements are impossible without electronic means, but are relatively simple with the ion gauge, a typical electronic device. Without measurements of this kind, the separation of uranium isotopes in the atomic bomb, either by the electromagnetic or the gaseous diffusion methods, would have been impossible on a production scale.

Still another field is the measurement of very short time intervals. In radar, in shoran, and in the absolute aircraft altimeter, distances are measured by noting the time required for an electromagnetic wave to travel from the test point to the target and back again. Since these waves travel at 186,000 miles per second, the time intervals at which they traverse ordinary distances are very short. A wave will travel from the apparatus to a target 500 feet away and back again, in just about one microsecond. Yet it is possible to measure distances to an accuracy of 50 feet or better, which require measurement of time intervals to an accuracy of one tenth of a millionth of a second. Without electronics, such small time intervals, and such extreme precision, are absolutely impossible.

These are but a few of the fields in which electronic methods make possible measurements that were impractical or even impossible by older methods. They are taken at random from a variety of different fields merely to illustrate the amazing versatility of electronics as a measurement tool. Some of these methods have been developed and perfected highly, and are accepted now as standard and orthodox, such as the cathode-ray oscilloscope, the pH meter with glass electrode, and the self-balancing photoelectric potentiometer.

LIMITATIONS OF ELECTRONIC METHODS

From the wide range and the brilliant accomplishment of the foregoing examples, it might seem that electronics is the proverbial "answer to a maiden's prayer" in the making of measurements, and that electronic methods will supplant the methods now in use. It must be remembered, however, that electronic methods must do a better job than existing methods, if they are going to survive. *Measurement is more than a science, it is also an art.* It is not enough to develop a method or device which merely will accomplish measurement of a given quantity. A satisfactory measuring instrument entails much more than that. It must be a skillful and judicious compromise between the contradictory requirements of accuracy, sensitivity, ruggedness, reliability, stability of calibration over a long period of years, simplicity of construction, ease of maintenance, compactness, and low cost. This is a large order, and much money, effort and brains have been expended in balancing these conflicting requirements, in the instrument mechanisms which we use so nonchalantly today. Knowing these complicated requirements and the difficulty of their achievement, the instrument engineer is naturally cautious about new methods that may bring in their wake new troubles.

Unfortunately, electronic methods *do* have troubles all their own. In the first place, they are handicapped in industrial use because specially trained technicians and special service tools are required to maintain them. Imagine entrusting the service of a balanced photoelectric cell circuit with high-gain direct-coupled amplifiers to the ordinary industrial electrician who is used to servicing motor starters and switchgear, and whose principal tools are a screwdriver and a monkey wrench. Even though electronic service men are being trained in large numbers, it is still true that the average electrical maintenance man knows little or nothing about electronic equipment, and that the average industrial plant does not have an electronic specialist.

Second, most electronic equipment is seriously lacking in ruggedness. This statement may be challenged by electronic engineers and designers who point to the satisfactory life of ordinary radio equipment, and particularly to the satisfactory performance of communications equipment in radiobroadcasting stations and telephone toll plants. However, the conditions of operation of such equipment are vastly different from those demanded in industry. The average home radio is operated only a few hours per day. It is in a living room where temperatures do not vary widely, where the air is reasonably clean, and there are no unusual destructive influences. In the broadcasting station or toll plant, even though operation may be for 24 hours per day, conditions are still ideal for cleanliness, freedom from vibration, and control of operating voltages, and in addition, there is an ever-present skilled technician to check the equipment at regular intervals and make adjustments or replacements as needed.

Industrial use is a very different story. A complicated electronic instrument as likely as not will be mounted on a heat-treating furnace or next to a forging hammer. The equipment must operate 24 hours a day, often under violent conditions of vibration and shock, in the presence of smoke, dirt, and corrosive fumes, often in the presence of steam or dampness, usually over wide ranges of temperature in unheated buildings, and in the presence of such damaging influences as flying scale, dripping oil, tenaciously clinging textile lint, or fiercely abrasive dust. Furthermore, the instrument must operate with widely fluctuating line voltages, commonly ranging from as low as 90 to as high as 130 volts. These voltages will have both long period changes and rapid fluctuations. In spite of all of these untoward influences, there will be no skilled technician to check or adjust the apparatus, and probably no one in the whole plant who knows how it works or who knows how to do anything more than change a tube. For such conditions, which are normal in industrial service, an entirely different kind of design is needed from the designs commonly used for home radio or commercial communications apparatus. These new designs must be based on different materials, more rugged components, improved construction, and often on different basic circuits. Neither the parts nor the methods used in ordinary radio work are good enough for a measuring instrument.

The foregoing limitations apply to electronic equipment in any industrial application. However, there is a third limitation that is of specific importance in the field of measurement. This is the difficulty in applying vacuum tubes to *calibrated* circuits, when those tubes change their characteristics gradually with age, change them sharply with fluctuating operating voltages, and often change with varying temperature, and when two tubes of the same nominal characteristics are seldom identical. As a result, tubes seldom can be placed in calibrated circuits without very special precautions. One approach is to hold applied voltage constant by special regulating devices or circuits, thus offsetting the most serious source of change of the vacuum tube's quantitative characteristics. A second approach is to compensate these changes when they occur by using balancing circuits, or such schemes as degenerative feedback. A third approach is to provide a self-contained calibrating standard within the instrument, or to arrange the circuit so there is some simple means of checking and adjusting any drift or change. A fourth approach is to use a vacuum tube so that its constants do not enter into the calibration. This last method is the most difficult and the most limited of application, but the most satisfactory. For example, it is possible to use vacuum tubes in the controlling element of a telemeter which produces an output current proportional to position of a primary measuring element and yet have that current entirely independent of tube constants, the calibration being contained in an element external to the tube with the tube being merely a coupling device. These methods of circumventing the variable characteristics of vacuum tubes usually require additional circuit elements, increasing complication and cost, decreasing reliability, and making service more difficult.

A fourth limitation of electronic equipment in measuring instruments is that of obsolescence. The electronic art is advancing so swiftly that a piece of communication testing equipment may be obsolete in two or three years. A home radio may be obsolete in five years. But the purchaser of an elaborate and expensive measuring instrument or controller for industrial use may expect to amortize it at the same rate as his machinery, over a period of 10 or even 20 years. Every reputable builder of measuring instruments has many instruments in service that are 20 to 30 years old, and must keep those instruments in good repair and be able to supply replacement parts. With the swift change in electronic components, such replacements often become difficult if not impossible. The components change in size, method of mounting, in rating, in method of connection, and so forth.

Last is the matter of inferior components. Such things as tubes, sockets, capacitors, resistors, transformers, and switches are designed for the high-volume, low-cost, mediocre-quality market supported by home radio receivers. These components are not good enough for rugged industrial service, are not good enough for stable, long-lived, accurate measuring instruments. Resistors burn out or change their values with time or with temperature. Capacitors blow out, develop high leakage currents, or change capacity widely with temperature. Switches and sockets develop bad contacts, and in the presence of dirt, corrosion, or voltage surges, arc over the insulation. Transformers develop grounds and electrolysis consumes their fine wire windings. Tubes lose emission or change characteristics in entirely too short a time, develop loose bases and pins under conditions of vibration, arc over their leads or bases under voltage surges, become microphonic, show leaky insulation under high humidity, or develop leaks or even short circuits between closely spaced internal elements. These weaknesses are not tolerable in industrial measuring equipment. A line of carefully engineered components designed for heavy-duty industrial service is needed sadly.

POSSIBILITIES FOR USE

Electronic methods have possibilities in the measurement field that are as far-reaching as they are intriguing. They can make some measurements better, or faster, or cheaper than older methods. Their most important use, however, results from their ability to make measurements heretofore impractical or impossible. Electronic methods offer extreme sensitivity, great amplification, unlimited speed, smooth, stepless, wide range, easy control, and fully automatic operation. Even with all these advantages, electronic methods are not a cure-all. They face the rather formidable limitations of lack of ruggedness, difficulty of service, limited life, instability of calibration, obsolescence of components, and the difficulty of obtaining components properly designed for heavy-duty service.

As a result of this group of advantages balanced by a corresponding group of limitations, the wise instrument engineer is fascinated by the boundless possibilities of electronic methods applied to his difficult art, but will adopt those methods only after they have been perfected to meet his complicated and very rigid requirements.

Electronic Recording Instruments

THE RECORDER FIELD is a very large one and is too large to be covered in any one meeting. For that reason the conference on electronic instruments at the 1946 AIEE summer convention in Detroit, Mich., on June 24 was limited to electronic recording instruments for potentiometric and bridge-type measurements. W. R. Clark (M '44) chairman, AIEE joint subcommitee on electronic instruments, and supervisory research technologist, research department, Leeds and Northrup Company, Philadelphia, Pa., presided and in his opening remarks recounted the brief history of electronic recording instruments presented here as an introduction.

The article presents digest of several of the discussions which took place at the conference. The digests are based on talks presented by A. J. Hornfeck (M '43) research engineer, Bailey Meter Company, Cleveland, Ohio; W. P. Wills (M '42) engineer in charge, development division, The Brown Instrument Company, Philadelphia, Pa.; A. J. Williams, Jr. (M '45) chief of electrical division, research department, Leeds and Northrup Company, Philadelphia, Pa.; V. L. Parsegian (M '46) director of research, C. J. Tagliabue Division, Portable Products Corporation, Brooklyn, N. Y.; and George Keinath (M '37) consulting engineer, Connecticut Telephone and Electric Division, Great American Industries, Inc., and R. K. Hellmann (M '45) assistant chief engineer, Connecticut Telephone and Electric Division, Great American Industries, Inc., Meriden, Conn.

A Brief History

W. R. CLARK

AUTOMATIC RECORDING of various phenomena is being used more and more each day and is spreading to all fields of industry. During the war, automatic recording and controlling methods were one of the main factors that enabled this country to far surpass the production efforts of all other nations. The atomic bomb would not have been possible without the recorders and controllers that were so essential in this development.

A brief history of some of the recorders which proceeded the electronic recorder for potentiometric or bridge-type measurements is of interest. About 1898, the Cambridge Instrument Company in England started to manufacture a recorder designed by Professor Callendar. This recorder, which was one of the earliest to appear on the market, was a continuous-balance recorder. The unbalance in a bridge or potentiometer circuit was detected by a galvanometer which actuated a motion through relays to rebalance the circuit. This null-type recorder, due to its very delicate detector system, was not satisfactory for general industrial use.

About 1910 several recorders for potentiometric and bridge-type measurements were marketed in this country but the first really practical high sensitivity recorder which was rugged enough for general industrial use, appeared on the market in 1913. It was invented by M. E. Leeds of the Leeds and Northrup Company and was a step-by-step mechanical recorder of comparatively simple construction, requiring about 22 seconds for full scale rebalance. This recorder, with some modifications, is still very popular today.

It was not until about 1931 that the first electronic recorders for null-type measurements (potentiometric or bridge type) became available for general industrial use. One of the earliest of these was the Leeds and Northrup "Speedomax." It used a potentiometric type of measurement in which the d-c unbalance was converted to alternating current by a chopper, then amplified, and the resulting voltage used to fire one or the other of two thyratrons. Each thyratron controlled the current through one field of the motor driving the slide-wire. When an unbalance occurred, the proper thyratron would fire and the motor would drive the slide-wire to the new balance position. A voltage proportional to speed was obtained from a tachometer and induced in the measuring circuit to prevent overshooting. Ranges as low as 2.5 millivolts were possible with this instrument and its speed was 1.5 seconds for a full-scale unbalance.

The Bailey Meter Company's "Galvatron" recorder appeared about 1933. It utilized a sensitive galvanometer in the measuring circuit. The galvanometer had a short period and the needle was clamped periodically to make an electrical contact of a duration proportional to the galvanometer deflection. The contacts were in the grid circuits of two vacuum tube relays which amplified the current flow to operate a reversing motor, which drove the slide-wire to rebalance the measuring circuit.

Another early electronic null-type recorder was made by the C. J. Tagliabue Manufacturing Company about 1933. It employed a beam of light, mirror-type galvanometer, a phototube, an amplifier, relays, and a motor. The light reflected from the mirror of the galvanometer connected in the measuring circuit would strike the photoelectric cell. Any change in light would produce a voltage in the output circuit of the amplifier which would operate the relays to drive the slide-wire motor toward the balance position.

The Bell Telephone Laboratories have made quite a few high-speed electronic recorders, but they have been designed to make attenuation or noise level measurements and are not applicable for potentiometric or bridge-type measurements nor are they available to the general industry.

For the past few years, practically all of the recorder manufacturers have been selling electronic recorders of one type or another. The Brown Instrument Company's "Electronik" uses a converter to change the d-c unbalance of the measuring circuit to alternating current and an amplifier to amplify this unbalance so that it will control a 2-phase induction motor which positions the slide-wire in the measuring circuit. The Foxboro Company's "Dynalog" amplifies the unbalance and uses it to position a plunger actuated by solenoids. The plunger adjusts a capacitor in the a-c bridge circuit which contains the primary element (strain gauge, resistance thermometer, or other signal device), and hence rebalances the bridge.

The Bailey Meter Company's newest recorder eliminates the galvanometer of the "Galvatron" recorder and uses a d-c to a-c converter in the measuring circuit, amplifies the alternating current that occurs when the measuring circuit is unbalanced and uses the amplified alternating current to control a two phase induction motor which moves a slide-wire to rebalance the measuring circuit. The Leeds and Northrup Company have on the market a "Speedomax" type *G* recorder which is similar to the early "Speedomax" except that a power vacuum tube controls a 2-phase induction motor which adjusts the slide-wire, in place of the thyratron-controlled series reversing motor.

Sweep-balance recorders such as that made by Great American Industries, Inc., are the most recent developments in the recorder field, and electronic devices are being applied in their operation.

Electronically Operated Instruments for Industrial Measurement

A. J. HORNFECK

ALTHOUGH a relatively new development in the field of process instrumentation, the electronically operated null-balance recorder has proved to be a versatile and powerful aid to the optimum operation of these processes. It has solved many complex recording problems that appeared to be extremely difficult, if not impossible, with mechanical instruments. Standardization on basic instrument design for a great variety of measurement is perhaps the greatest advantage over mechanical and conventional electrical instruments.

The obvious advantages of the electronically balanced recorder such as high sustained accuracy, high torque output, and sturdiness as regards vibration and severe ambient conditions are of importance. However, of still greater significance are the versatility and flexibility of the system. With minor adjustments of the measuring circuit and arrangement of components, the same basic instrument is capable of measuring nearly all process variables. Furthermore, the electronic instrument can be used to actuate any type of control whether electric, pneumatic, or hydraulic. Algebraic computations of a simple or complex nature involving combinations of measured quantities can be carried out readily with the general system using basic measuring circuits and relatively standard components.

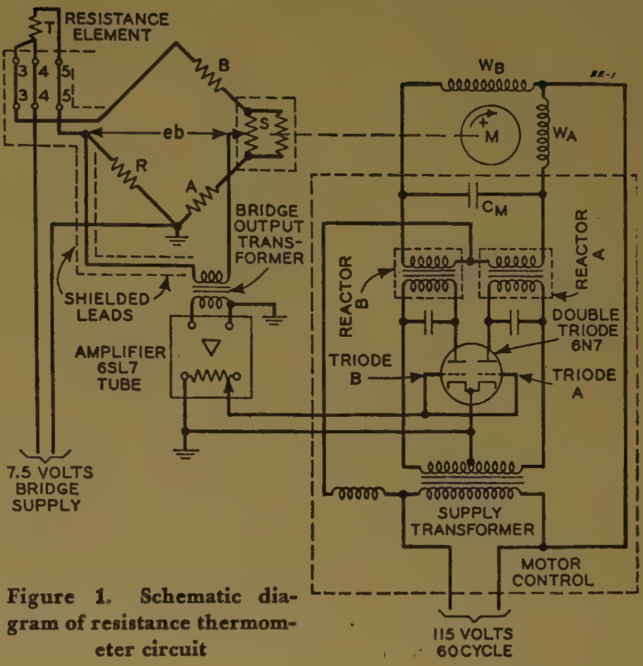

Figure 1. Schematic diagram of resistance thermometer circuit

THE BASIC CIRCUIT

While it is realized that electronically actuated instruments of the null-balanced type are electromechanical as well as electronic, the commonly accepted meaning of the term "electronic" is used to describe instruments which depend in a basic way upon electron tubes for their operation. In the transmitter or primary measuring device the quantity being measured is converted directly or indirectly into an electric potential current, resistance, impedance, or a ratio of any of these factors. For example, quantities such as pressure, fluid flow, and liquid level perhaps are converted most frequently into a force or motion by means of a float, diaphragm, bellows, liquid column, or helical tube. These devices then are employed to actuate an electric transmitter such as the solenoid core or a variable capacitor or a resistance slide-wire. In many cases, fortunately, the measured quantities such as temperature, stress or strain, or percentage of a gas in a mixture are convertible directly into an electrical quantity by means of a resistance, thermocouple, and d-c generator. Furthermore, in some applications as for gas analysis by spectroscopic methods, high vacuum measurement, pH determination (hydrogen ion concentration), smoke density, or radiation intensity, the measuring device itself may be truly electronic in nature.

The motor driven follow-up in the null system may be a resistance slide-wire, a variable inductor, or a variable capacitor. A change in the process quantity will produce a corresponding change in the converted electrical variable at the transmitter. Consequently, an unbalance between the transmitter and follow-up index will occur to produce a direct or alternating unbalanced voltage of the measuring circuit. This voltage is detected and amplified and the resulting output is applied to a phase-sensing motor-control circuit causing the follow-up motor to rotate in such a direction as to rebalance the system. The per cent readjustment of the follow-up is then an accurate measure of the quantity.

The instrument was developed originally for a-c operation using a platinum resistance temperature detector in a Wheatstone bridge. Its use since has been extended to a large variety of a-c bridge measurements as well as to the recording of direct voltages and currents. Figure 1 shows the complete schematic circuit for temperature measurement using the platinum detector. The unbalanced voltage of the bridge is proportional to the magnitude of the change in resistance of T produced by a change in temperature. Its phase relative to the supply voltage depends on the direction of unbalance. This bridge output signal is amplified by a 2-stage resistance-coupled amplifier having a voltage gain of about 2,500. For narrow temperature ranges requiring high sensitivity the relatively low-resistance bridge is coupled to the high-resistance amplifier input by means of a high-ratio step-up transformer to obtain a total voltage gain between bridge and amplifier output of 40,000. All or part of this amplified signal is applied to the grids of the 6N7 double-triode motor-control tube. The voltage applied to the plates of this tube is obtained from a center tapped secondary winding of the supply transformer whose primary winding is supplied from the same a-c source as the supply to the measuring circuit. Since the plates of the 6N7 are 180 degrees out of phase and the grids are in phase, the plate currents of the two sections of this tube selectively are controlled by the phase relation between grid and plate voltages.

The plate circuits of the motor control tube are coupled to the motor windings through saturable reactors A and B. The flow of alternating current through these reactors is controlled by the direct current flowing in the tube plate circuit. If the unbalance of the measuring circuit is such as to give an amplifier voltage in phase with the plate of triode A, this section will pass more current and triode B less current than at balance. Consequently, motor current will flow through reactor A directly through winding W_A and through the motor capacitor and winding W_B. This phase relationship of winding currents will cause the motor to rotate in a direction to rebalance the measuring circuit. By the same analysis, unbalance in the opposite direction will produce an amplified voltage in phase with triode B and a resulting motor rotation opposite to what it was before, but again in a direction to restore balance.

The limit of flexibility of the system so far described is the fact that it is not suitable to d-c measurements. However, for the measurement of variables which are translated into d-c potentials, a suitable d-c to a-c converting device is interposed between the measuring circuit and the a-c amplifier. The system devised for this conversion uses a saturable core reactor type of bridge converter which transforms the reversing polarity d-c unbalance into an amplified alternating voltage of reversing phase.

The converter consists of two saturable reactors arranged in an a-c bridge circuit with one adjustable tap and two fixed resistors. The output of this bridge is coupled to the electronic amplifier by means of a step-up transformer. The reactors are of special design and use a high permeability core material so that they are extremely sensitive to minute d-c fields. The windings are connected in such a way that a change in d-c input to the reactors changes in a differential manner the reactances of the two reactors, thus unbalancing the bridge, and producing an alternating voltage in the primary of the output transformer. The alternating output voltage of the bridge is proportional to the difference in reactance of the two units, and its phase relative to the bridge supply is determined by whether reactance A is larger than B or smaller. The magnitude and phase of the output voltage, therefore, depends on the magnitude and polarity of the d-c input.

The unbalance voltage output of the converter bridge is increased further in the amplifier and then is introduced into the motor control circuit, causing the motor-driven potentiometer slide-wire to be reset so that the d-c input to the converter bridge from the potentiometer circuit is zero, thus restoring balance to the converter bridge. The resulting position of the contact on the motor-driven potentiometer slide-wire is an accurate measure of the unknown potential.

One circuit which has been used extensively for the transmission of position or motion uses an adjustable core transformer of solenoid form as the transmitter. The core of the transmitter is moved by the element being measured. Since the magnetic flux linkage between the primary winding and each of the secondaries is determined by the core positions, the ratio of the induced voltages will vary with this core position.

An electrical bridge is formed by the two secondary coils and the resistances on either side of the slide wire contact at the receiver. Since the bridge is balanced when the resistance ratio is equal to the voltage ratio, the rotation of the slide wire is proportional to the core motion and consequently to the quantity being measured.

This circuit is adapted especially to determination of differential pressure, as for example, in the measurement of flow, liquid level, viscosity, and other factors, since the moving core can be inside a pressure housing.

CALCULATING SYSTEMS

Circuits for totalizations, subtractions, multiplications, ratio determinations, and combinations of these have been devised using basic standard components. Furthermore, by means of cam positioning of the follow-up and recorder pen, nonlinear relations such as exponentials between primary quantities and converted electrical quantities can be converted readily to linear factors for uniform scales and algebraic combinations. One such system has been devised for gas-flow metering with compensation for changes in gas flow produced by both pressure and temperature variations over wide ranges.

D-C to A-C Conversion Systems

W. P. WILLS

THE MEASUREMENT of d-c potentials of the order of 10^{-6} to 10^{-9} volt without the use of sensitive galvanometers has been accomplished only within recent years. Such voltages are encountered in thermopiles, thermocouples, and other similar devices. The small power available from such devices has required the use of delicate galvanometers in conjunction with elaborate mechanical means for recording and controlling functions. Because such galvanometers were of slow time period the recording and controlling action was limited in its speed of response. Direct amplification of the d-c potentials often has been suggested as a means of eliminating the sensitive galvanometer. However, the normal instability and the inherent dependence of d-c amplifiers upon tube characteristics and supply voltage have eliminated them from general use. The ordinary a-c amplifier has so many advantages over the d-c amplifier that it generally is used in all methods of amplifying small d-c potentials. In order that the a-c amplifier may be used, a system for converting the initial d-c potential to alternating current must be accomplished. At this low level of potential a device for changing direct to alternating current is called a "converter." A device which changes amplified alternating current back to direct current is called a "reconverter."

One of the first converters developed when the need for such devices was recognized in 1916 employed a circuit comprising a plurality of amplifier stages and a source of d-c potential connected to the input of the amplifier through a manually-operated switch. A meter in the output responded only to a-c changes in the amplifier. A later improvement in 1919 involved a radiation thermopile connected through a continuously operating switch to the output of an a-c amplifier. The output of the amplifier applied to a pair of head phones produced an audible sound when d-c potentials were chopped by the continuous action of the switching. In a similar device a motor-driven switch in a thermocouple circuit interrupted direct current flowing in the primary winding of a transformer which induced an alternating voltage in the secondary winding. This alternating voltage was amplified by a vacuum tube, and a meter in the output circuit gave a reading proportional to the temperature measured.

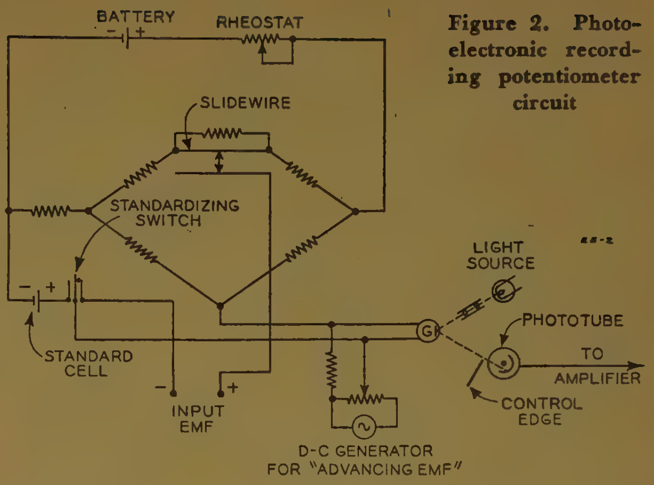

Figure 2. Photoelectronic recording potentiometer circuit

From 1932 to 1940 many new systems were devised to eliminate the difficulties caused by mechanical switches. To eliminate mechanical contacts, one suggestion was the substitution of a unilateral conductive device such as a copper-oxide rectifier as the converter. In 1932 use of a carbon button microphone as a converter was developed. The microphone was employed to vary periodically the direct current so that the resultant alternating voltage could be amplified. Resistance of the microphone was varied by means of an electromagnetic vibrator mechanically connected to the microphone button.

In 1934 the use of a selenium cell as a converter was disclosed. Illumination from a gas discharge tube, actuated by the supply voltage frequency, was directed on the selenium cell to give a continuously variable resistance. Continuous variation of capacity and inductance have likewise been disclosed.

The use of a saturable-core reactor type of converter was introduced in 1939. Multiple saturable core reactors were set up in a bridge circuit and the bridge was energized with alternating supply voltage. The magnetic balance of the bridge was upset by the application of a d-c potential and output connections of the bridge delivered an alternating voltage proportional to the direct current applied. Electronic converters have also been suggested, the first of which was in 1937. A direct potential was applied to the grid of a pentode vacuum tube and an alternating voltage was supplied to the screen grid so that the plate current was modulated by the alternating voltage and the value of the alternating plate current was proportional to the direct current applied.

Other forms of converters have been suggested and used. There have been cathode ray tube converters, radiation-sensitive resistance elements, twin vacuum tube-bridge converters, and numerous variations of all of these devices. It is important to note that after this era of eliminating mechanical contacts from 1941 to date a tremendous advance has been made in improvement of mechanical contacts, and today they are practically the only device available for use in measuring potentials of the order of 10^{-7} to 10^{-9} volt.

In 1941 an electronic potentiometer[1] for temperature measurement and control was made available for general industrial use. This potentiometer uses a vibrating reed type of converter in place of the conventional galvanometer. The conversion system has a sensitivity of 10^{-6} volt with a stability of 5×10^{-7} volt when used in a standard production instrument. Through five years of industrial experience the converter has proved to be a thoroughly dependable device for the purpose intended. During the war General Motors Research Laboratories designed a d-c conversion system[2] for measurement of potentials to the level of 10^{-9} volt. This system uses a motor-driven mechanical switch to convert direct to alternating current and after amplification the alternating current is changed back to direct current by a second mechanical switch in synchronism with the original conversion. This system had a stability of 4×10^{-9} volt over relatively long periods of time. By using this device as a pre-amplifier for an electronic potentiometer similar to the one described, it is possible to have a rugged and satisfactory recording system for d-c potentials of the order of 10^{-9} volt.

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The Input Transformer Problem

A. J. WILLIAMS, JR.

THE PREFERRED WAY to use electron tubes for measurement is in a-c amplifiers, even though the measurement to be made is by d-c means such as the electromotive force of a thermocouple. Based on the use of such amplifiers, a development was undertaken in 1929 toward a faster and more sensitive d-c potentiometer recorder.

To convert the direct current to alternating current, a carbon telephone transmitter was used. It was driven mechanically by a polarized electromagnet. An input transformer was used to insulate the thermocouple from the amplifier and its power supply. Because the thermocouple impedance was low compared to the input impedance of the electron tube, a voltage step-up was possible and desirable in the input transformer.

In February 1930, an experimental recorder was operated with a range of 400 microvolts and a zero stability to about 1 microvolt. Operation was satisfactory, but the setup was extensive and required batteries for the electron tube power supply in order to avoid the hum problem resulting from an a-c or rectified a-c supply.

By 1933 the development had progressed to the point where instruments were made commercially available in a more compact form. The greatest single factor which made this possible in one recorder was the input transformer. Its high secondary impedance (15 megohms) allowed a voltage step-up of 1,000 so that the signal from the thermocouple could override the hum of the first electron tube even though it had an a-c heater. The high secondary impedance was obtained by the use of a nickel alloy core. Permissible minimum range of the recorder was set at 2.5 millivolts, since its noise (including a-c hum) could be held to about 2 microvolts.

Improvement through the years has succeeded in producing smaller and simpler electronic potentiometer recorders.[1] Reduction in size of the input transformer is permitted by compact construction of the core and its magnetic shields. The input transformer is a magnetic device, and it operates at the lowest power level in the recorder (the same power level as the input to the first tube, to which it is connected). For these reasons the transformer is highly susceptible to pickup from stray magnetic fields.

One step toward minimizing this pickup is the use of core-type construction, now commonly known as "hum bucking," because equal turns on the two legs of the core give equal and bucking voltages for changes of flux entering the core from a uniform external (or stray) magnetic field.

The second step toward minimizing the pickup is the use of the quadruple concentric magnetic shields which, though thin, are effective, because a highly permeable nickel alloy is used. The value of core-type transformers in symmetrical magnetic shields was proved for instruments as early as 1930. The over-all effectiveness of core-type construction and symmetrical magnetic shielding is to reduce the pickup from a stray field of one gauss at 60 cycles per second to about 50 microvolts on a secondary winding wound to 0.7 megohm.

It is interesting to note that this transformer, in both its core and its magnetic shielding, benefited from research done by H. D. Arnold and G. W. Elmen prior to 1923, with the idea of building a better submarine communication cable. They called the high permeability 78.5 per cent nickel alloy Permalloy.

A transformer with a high step-up ratio has been used with an amplifier to detect direct voltages close to the limit set by thermal agitation (Johnson noise), under certain conditions. In particular, at 300 degrees Kelvin in a 2-ohm circuit with a pass band of one cycle per second, the peak-to-peak noise calculates to 0.0014 microvolt. The measured value was 0.0017 microvolt. Liston, Quinn, Sargeant, and Scott[2] have worked to lower voltage in a circuit of lower resistance. Roess[3] has worked to lower voltage (alternating current only) with a system of narrower band width.

It is interesting to note that the input transformer can work down to these low voltage levels without itself introducing noise. It is stated that 78.5 per cent nickel alloy, when properly heat treated, is remarkably free of magnetostriction and consequently is not microphonic. This is very fortunate and the story might be quite different if it were not so.

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A New High-Speed Recording Potentiometer

V. L. PARSEGIAN

FAST SELF-BALANCING POTENTIOMETERS were improved vastly during the war for the rapid recording of thermocouple voltages. In certain of these, the direct current of the thermocouple is converted by mechanical oscillators to alternating current, and amplified to drive the balancing motor. These give good vibrationproof performance, but because their input circuit is connected directly to the power amplifier through the converter one must take care to shield the input against electromagnetic pickup such as results from operation of switches, and must avoid grounding both the instrument and thermocouple, because multiple grounds can introduce currents which are converted and amplified to cause large errors in the record.

The following describes an instrument of the photoelectronic type in which equal speed of recording is attained without pickup difficulties. To make this instrument possible a new galvanometer of rugged design was developed, having low inertia, short period, and capable of withstanding considerable vibration and shock. Its narrow coil is held taut between short strong suspensions, and a small mirror reflects the movements of the coil,

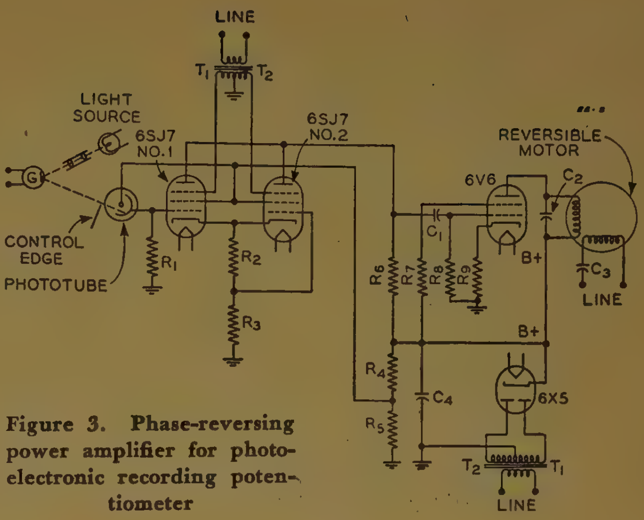

Figure 3. Phase-reversing power amplifier for photoelectronic recording potentiometer

permitting complete electrical separation of input and power circuits and thereby avoiding the ill effects of pickup and multiple grounding.

THE POTENTIOMETER CIRCUIT

Figure 2 illustrates the potentiometer circuit. A beam of light directed onto the mirror of the galvanometer coil is reflected toward a phototube in back of a control edge. When the galvanometer is undeflected a long narrow light image is split by the control edge. On deflecting, the galvanometer sends less or more light to the phototube, and the amplifier responds by driving the motor and recorder carriage up or downscale to restore balance.

When the carriage moves, the rotating galvanometer coil lags behind the carriage by an amount proportional to the speed of the carriage.[1] To cancel the effect of this lag and prevent hunting, an "advancing electromotive force" is applied to the galvanometer by a small generator driven by the carriage motor.

THE AMPLIFIER CIRCUIT

Figure 3 illustrates the amplifier and power circuit. The direction of rotation of the split-phase motor driving the recorder carriage is determined by the quadrature phase relation of the currents in the two field windings. The power for the auxiliary winding is obtained through the 6V6 power tube, the output current and phase relation of which is controlled by the voltage imposed on its grid by the two 6SJ7 tubes.

The two 6SJ7 tubes working together with the photoelectric cell combine to reverse the phase of their output voltage by 180 degrees depending on whether the reflected light is on or off the phototube. These tubes have common plate, screen, and cathode connections, but the suppressor grids are connected to opposite ends of the transformer secondary, becoming alternately positive and negative. The current passing through each tube then is influenced both by the bias of the control grid and by the phase relation of the suppressor voltage.

In the balanced position an intermediate value of

The development of the potentiometer was carried on with the co-operation of C. O. Fairchild, S. Swedlow, and Mrs. L. Slack together with others of the Portable Products Corporation, C. J. Tagliabue Division, laboratories.

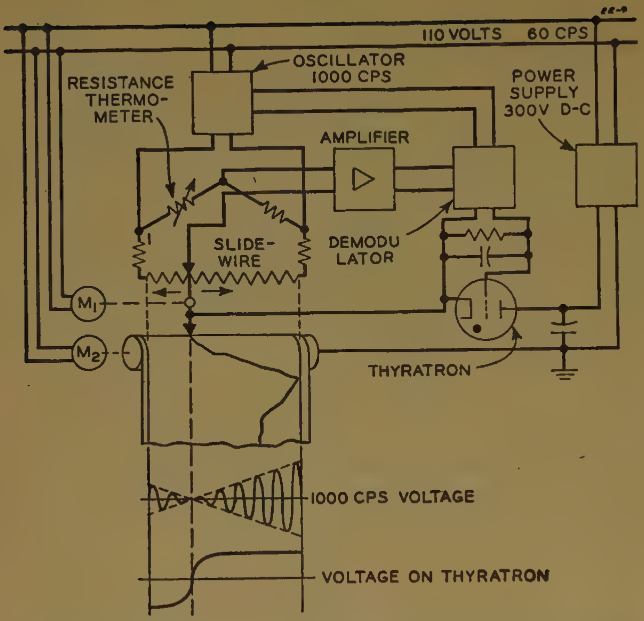

Figure 4. Schematic diagram of sweep-balance recorder showing Wheatstone bridge circuit and strip chart recorder

illumination reaches the photoelectric cell and each tube conducts equally, so that a reduced voltage having 120-cycle form is applied to the motor. When the photoelectric cell illumination is increased by galvanometer deflection, tube number 1 conducts more, increasing the bias across R_2 and thereby cutting down the output of tube number 2. The motor then receives a high 60-cycle voltage, of proper phase to turn it to drive the carriage downscale. When the illumination is decreased the output of the first tube decreases, permitting the output of the second tube to increase and to apply a high voltage having a phase 180 degrees displaced from the first, to drive the carriage upscale.

PERFORMANCE CHARACTERISTICS

This instrument was designed to be suitable for field use by the meteorological branch of the Army Signal Corps. The carriage travels across the 10-inch chart in one second, and can reach a balance without overshooting within an accuracy of 0.2 per cent of full range in about 1.5 seconds for full scale travel. This accuracy and a sensitivity of 0.1 per cent are available when the range of the potentiometer exceeds approximately 20 millivolts.

Neither the galvanometer, phototube, nor the other tubes are calibrated units, so that the complete balancing amplifier unit including the galvanometer and light source can be replaced interchangeably among instruments of the same type.

In size, weight, and simplicity the instrument resembles the ordinary slow strip-chart recorders. It requires no special mounting, and is almost as much at home in the throbbing compartment of an airplane as it is on the ground. Its high speed is of value also for recording ordinary voltages and for spectroscopic recording when a preamplifier of conventional type is used.

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Sweep-Balance Recorders

GEORGE KEINATH
R. K. HELLMANN

SWEEP-BALANCE RECORDERS are a new kind of automatic potentiometers different from step-by-step recorders and continuous-balance recorders. A Wheatstone bridge circuit (Figure 4) is combined with a strip chart recorder in such a way that the slide contact is co-ordinated with a stylus traveling across a chart, which consists of voltage-sensitive paper such as "Teledeltos," the medium used in Western Union facsimile recorders. The conventional null galvanometer or null motor in the output of the bridge has been replaced with a high-speed null relay which may be either of the electromagnetic or electronic type. The paper is marked only when a discharge from a capacitor is passed from the stylus to the paper and the grounded drum under the chart. The connections are such that the discharge is released when the output voltage of the bridge becomes zero or the phase of the output voltage reverses with respect to the input voltage (bridge balance).

For the sake of simplicity Figure 4 shows a sweep-balance recorder in which the stylus and slide-wire contact comprise a unit which oscillates back and forth across the paper and potentiometer continuously. The actual designs, however, usually employ rotary potentiometers, charts of the drum or endless strip type (which may be considered as a variant of the drum type), and other devices.

With high speed electronic relays and a time delay of one millisecond, it is possible to reduce the sweep period to well below one second. If it were one second a timing error of one millisecond would cause a recording error of only 0.1 per cent of full scale.

This method of recording eliminates in a simple way many difficulties of other recording systems, such as unsatisfactory damping, overshooting, and hunting problems. Stylus and paper have a definite speed relative to each other which may be as high as 1,000 millimeters per second and need not even be constant.

The signals need not necessarily be electrical; they also may be of mechanical nature. Highest speed operation, however, can be obtained only with electrical signals.

One of the many design and application possibilities is shown in Figure 5, which illustrates an endless strip chart recorder used to trace 48 load-versus-strain diagrams in 24 chart frames, from 48 bonded-wire strain gauges and at a speed of 48 measurements and recordings every 7.5 seconds, or at a rate of 384 measurements in one minute.

The 48 gauges are connected to four 12-point circuit selector switches, each accommodating a group of 12 transmitters and connecting them successively to one of the four recording channels. Each channel consists of a sweep potentiometer, an electronic relay, and the discharge circuit. The outputs of two of these channels are connected to each of the two styli. The latter are arranged 5 inches apart on the 10-inch-wide chart and are positioned across the chart according to the variations of the load (here the *X* magnitude) by means of a more or less conventional continuous-balance or follow-up measuring system.

The paper can be moved at a maximum speed of 4 inches per second so that the chart (30 inches long with 24 frames 5 inches long by 2.5 inches high each) travels around in 7.5 seconds. With a 60-inch chart the 24 frames have a size of 5 inches by 5 inches and the travel time will be 15 seconds.

Whenever the stylus leaves one of the 12 frames along the chart the four 12-element switches are advanced one step by means of an electromechanical actuator and thereby connect the next set of gauges to the four measuring circuits. Within 0.625 second, the time of travel across one frame, two recordings are made with each stylus. Light and heavy discharge marks are used to distinguish the two gauges assigned to each frame. One use for recorders of this type is in testing airplane structures. Within one hour, from 48 gauges, 48 diagrams with 480 points each or a total of 23,040 measurements and immediately visible recordings can be obtained.

For recording a small number of variables as a function of time or some other factor, a drum recorder with a rotary stylus has been developed so that the diagram is normally stationary. This is a convenience at high recording speeds. It appears entirely practical to operate the stylus at five revolutions per second. With six magnitudes 30 points per second or 1,800 points per minute are produced, assuming, of course, that the electronic part of the recorder has been properly designed for such speeds.

A balanced demodulator has been found satisfactory for a-c operated sweep-balance recorders. The output of the measuring bridge is connected to the grids while the bridge supply voltage is connected to the plates of the demodulator tubes. The output of the demodulator consists of rectified and filtered d-c potential which is applied to the grid circuit of a thyratron. The latter becomes conductive when phase reversal occurs at the measuring bridge. At that point during each sweep cycle the capacitor is discharged through the thyratron and the paper. An energy of ten milliwatt-seconds and a time constant of one millisecond are given as average characteristics of the discharge.

The "resolution" along the sweep cannot be expected to be better than one cycle of the measuring frequency. It is clear that the percentage error thus introduced depends on the duration of the sweep. It is important, therefore, that the additional time delay introduced, for instance, by the necessary filtering is kept as small as possible.

Higher frequencies, full-wave demodulation, and phase-splitting circuits are available for the foregoing purpose. The design of such circuits is simplified somewhat by the fact that a strict balance of the two branches of the demodulator is not required as long as there is no shift of the zero-signal point.

In the development of this new type of recorder we had in mind three fields of applications:

First, in high speed production testing, picturizing tests on finished products without increase of testing time. The second field to which sweep-balance recorders can be adapted is production supervision. Pictures of production uniformity of as many as 24 or 48 machines can be obtained even with different kinds of machines and signal devices used on the same chart. A third group of applications comprises supervision of controlled or uncontrolled devices in which a number of essential data are brought together on one endless strip chart. In a power plant, for instance, fuel consumption, steam flow and pressure, temperature, voltage, current, accumulated energy, and even efficiency could

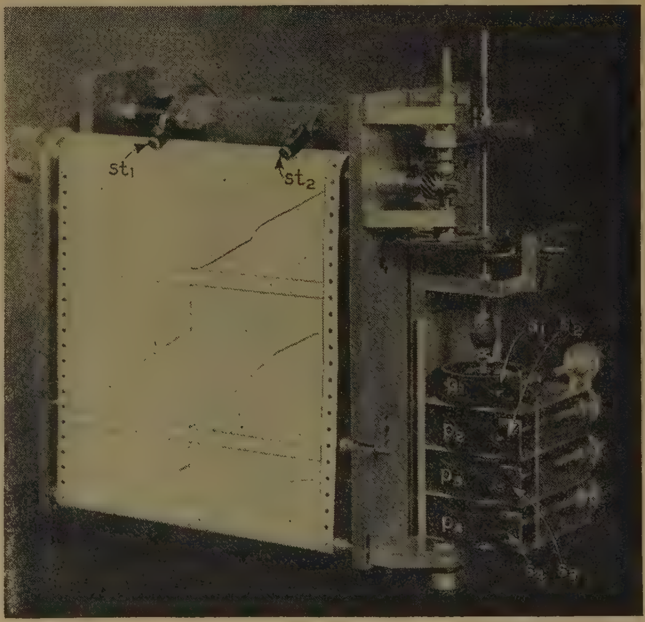

Figure 5. Endless strip chart recorder

ST_1 and ST_2—Recording styli p_1, p_2, p_3, p_4—Potentiometers
s_1, s_2, s_3, s_4—Group range switches

be concentrated on one chart serving as the "power station log."

In all these applications sweep-balance recorders are advantageous because the possibility of high-speed multiple recording. It should be kept in mind, however, that the magnitude of the input signals has to be the same as for other types of recorders and that, as always, lower signal levels and higher speeds call for wider tolerance in accuracy.

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Electrical Essay for Recreation

The following essay is presented for the recreation of the reader. Can you solve the problem?

In Figure 1 the conductors *a* and *b* connect the two electric devices *A* and *B*. If any current flow exists in this circuit, one of the two electric devices must be a source of energy, and the other a consumer.

The two conductors *a* and *b* are passing through the compartment *C*. An electrical engineer is placed in this compartment and he is asked to determine the amount of energy passing from one of the devices to the other, as well as the direction in which it is flowing. He may call for any electric instrument which he may need for this purpose, and he also may open the conductors for the insertion of any instrument.

The solution of this problem hardly can be called difficult and should be possible with nothing more than a background of high school physics. All that our engineer needs is an ammeter inserted in one of the conductors and a voltmeter measuring the voltage existing between the two conductors. The product of the two will give him the wattage, while the direction of the flow of energy can be stated easily if it is remembered that, at a device consuming electric energy, the current enters on the positive terminal and leaves on the negative terminal. Thus, if the conductor *b* should be positive with respect to *a*, and the current should be flowing in it from left to right, then the device *B* would be the consumer of electric energy while the device *A* would represent the source. In the case of alternating current, the two indicating meters will have to be replaced by elements of an oscillograph, the product of instantaneous current and voltage giving instantaneous power. If the average flow of power only is of interest, a wattmeter may be employed of course. Our engineer therefore can tell his boss proudly that nobody will be able to slip any electric energy through the compartment without him having a complete check on it.

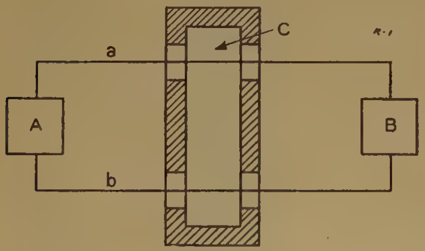

Figure 1

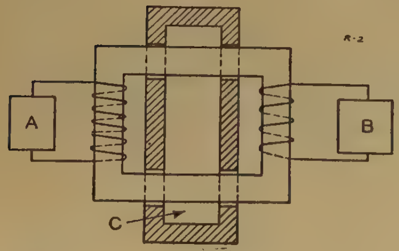

Figure 2

Now consider the arrangement shown in Figure 2. An open core transformer has its primary and secondary windings placed on opposite legs of the core, while the two remaining legs pass through the compartment *C*. If the device *A* should be an a-c generator, while *B* represents an a-c load, energy must be flowing through the compartment by way of the magnetic flux linking the two windings. We again ask our electrical engineer, placed in the compartment *C*, to determine the flow of energy. He may use any method or instrument suitable for this determination. For instance he may loop a wire around one of the core legs which will permit him to calculate the magnetic flux (with the frequency known, of course). The amount of magnetic flux, however, is no measure of the energy flow. As a matter of fact, with the primary voltage held constant, it will be at the highest value if the secondary winding is open.

If you were the unfortunate engineer stationed in the compartment *C* would you know of a way to measure the energy flow which undoubtedly exists through the compartment, or would you have to admit to your boss that somebody might be slipping energy right through the compartment you are stationed in, without your being able to determine such a flow?

WALTHER RICHTER (F '42)

(Electrical engineer, engineering development division, Allis-Chalmers Manufacturing Company, Milwaukee, Wisc.)

The Motional Mass of the Electron

A Reconsideration of Present Views Supporting the Lorentz and Einstein Equations

C. A. BODDIE

A new approach is offered to aid in the understanding of the physical phenomenon of the interaction of a moving electron and a deflecting electric field. Issue is taken with classical theory and proof is advanced to show that the mass of an electron is constant and independent of velocity but the inertia and elasticity of the electric field cannot be neglected. This material is scheduled for presentation as a conference paper for discussion at the AIEE winter meeting, New York, N. Y., January 27–31, 1947. ELECTRICAL ENGINEERING presents this material to stimulate debate on an important and controversial topic. Comments are invited.

IT is now well settled by both theory and experiment that the mass of an electron increases with velocity according to the equation of Lorentz.

$$m_v = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} \qquad (1)$$

where

m_v = the mass of the electron at velocity v

m_0 = the mass of the electron at rest

c = the velocity of light

Since all mass now is recognized as being electrical in nature this formula is accepted as perfectly general in its application.

The same formula is concurred in by the theory of relativity which being founded on certain postulates concerning space and time is presumably independent of any purely electrical theory and on that account is considered to apply to all mass whatever its nature and therefore general in its application.

When an electron of charge e falls in an electric field through a potential V, the kinetic energy acquired according to the principle of conservation of energy is set down as Ve, thus

$$Ve = m(v^2/2) \qquad (2)$$

During the fall the mass increases according to the formula of Lorentz. By considering with Newton, that the accelerating force at each instant is the rate of change of momentum $(d/dt)[mv]$ rather than mass × acceleration $m(dv/dt)$, the kinetic energy of the projectile is arrived at by integration of force × distance fallen through, giving finally the Einstein equation

$$Ve = m_0c^2\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}-1\right] \qquad (3)$$

Both the Einstein and Lorentz equations are now of general application in all departments of physics.

EXPERIMENTAL METHODS AND DATA

In the original experiments confirming the Lorentz equation, values of e/m were obtained by deflection methods. In more recent experiments intended to establish the value of e/m_0 with greater precision, nondeflection methods were used to avoid certain objections found in the deflection methods.

In the deflection methods high speed electrons derived from radium were projected toward a target passing simultaneously through a strong measured electric deflecting field maintained between a pair of closely spaced capacitor plates and a measured magnetic deflecting field either parallel to or at right angles to the electric field.

In the nondeflection experiments, electrons derived from a hot cathode were accelerated by falling through a measured high potential electric field. The resulting electron velocity then was measured directly by timing the flight over a known distance with reference to a known high frequency electric field.

The early deflection experiments of Kaufmann, while showing a definite increase in electronic mass with velocity, were not sufficiently accurate to distinguish between the two principal theoretical formulas as proposed by Lorentz and Abraham. More refined experiments by Bucherer, repeated by Neumann with still greater

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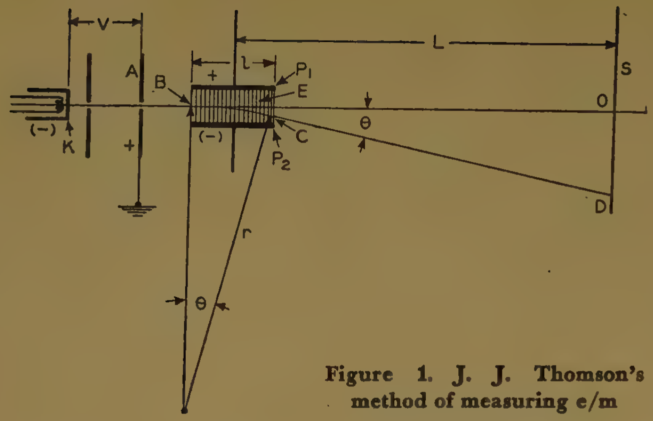


Figure 1. J. J. Thomson's method of measuring e/m

refinement gave results which confirm the accuracy of the formula of Lorentz for velocities up to 80 per cent of the velocity of light.

In the nondeflection experiments of Perry and Chaffee, the observed values of electron velocity were substituted in Einstein's equation which yielded values of e/m_0 in close accord with those of other methods. In these experiments electron velocities up to 30 per cent of the velocity of light were used. The results may be taken as confirmation of the Einstein equation up to that velocity.

While theory and experiment are in conclusive agreement in support of the accuracy of the Lorentz and Einstein equations within the ranges tested, there still remain a number of unresolved paradoxes in the general body of electrical theory, the existence of which are well known to workers in this field.

In attempting to resolve some of these inconsistencies, it has been discovered that in both the theories and in the supporting experiments, no allowance was made for the relative motion of high speed electrons in the electric field. This oversight is true of both the deflection experiments of the Kaufmann and Bucherer type and the nondeflection experiments of the Perry and Chaffee type.

A FALSE ASSUMPTION

In short, in all the experimental determinations of the value of e/m involving the motion of electrons in an electric field and in all the associated theories, classical and relativistic alike, it has been assumed without question that the mechanical pull on an electron moving in an electric field is precisely the same as the pull at rest. This rather sweeping assumption is general in all electrical theory and is accepted as self-evident or even axiomatic.

Stated more precisely it always has been assumed heretofore without question or debate, that the formula of electrostatics

$$F = Ee \tag{4}$$

is of general application for rest or for the uniform relative motion of the separate components E and e and holds exactly for all relative velocities clear up to and including the velocity of light!

That this far reaching assumption is unlikely to be true must appear self-evident once the case is stated clearly, unless indeed, it is held as in some quarters, that the electric field is a mathematical fiction rather than a physical entity.

THE CORRECT ASSUMPTION

If on the contrary, as we have every reason to believe, the electric field is some kind of physical entity, possessing not only the properties of longitudinal tension and lateral pressure as shown by Faraday and Maxwell, but possessing also lateral elasticity in the true mechanical sense and in addition is an entity possessing true mechanical inertia, laterally (both of which easily are demonstrated), it must be self-evident that an allowance of some kind must be made for the relative motion of an electron in an electric field.

We are confronted here, not with a question arising out of the speculative unrealities of relativity, but with a practical question involving a physical reaction between two physical entities in relative motion.

Granting that an electron and an electric field are physical entities possessing inertia and elasticity, we can be definitely certain that the interacting forces when the systems are in relative motion are different than when at rest. The case needs only to be pointed out to become self-evident. The question is not so much whether an allowance should be made in all experiments involving relative motion of field and electron but rather what that allowance should be.

It now must be clear that since none of the experiments and none of the theories relied on to demonstrate the motional mass of the electron ever have made any allowance for the relative motion of the electron in either a deflecting electric field or in an accelerating electric field, the results which have been obtained all must be in error by just the amount of this omission.

The consequences of this omission are far-reaching, involving not only the validity of present views on the motional mass of the electron, but other sections of electrical and physical theory as well. While altering appreciably some of our present views, the recognition of the existence of this motional factor results on the whole in greater unification and clarification; resolving a number of the heretofore insoluble paradoxes of electrical and physical theory. It removes much of the impenetrable mystery now attached to present views on the theory of relativity, reclaiming for practical everyday use much that now lies in the domain of pure mathematics.

Much additional light is thrown on the general nature of electrical and physical theory and on the relations between theory and experiment.

ORIGINAL ASSUMPTIONS

It is recognized in all quarters that the formula of Lorentz is founded on assumptions which are speculative. Lorentz assumed a medium essentially stationary and in accord with the views prevailing at that time which led to the famous Michelson Morley experiment, views now known to be speculative. Lorentz regarded an electron as a particle of pure electricity, as many do now, essentially spherical when at rest, but when in motion he assumed it to be shortened in the direction of motion by the factor $\sqrt{1-(v^2/c^2)}$, the other dimension remaining constant. Thus the Lorentz electron was a particle of electricity compressed into an oblate spheroid as a consequence of motion through a medium, the volume becoming zero at the velocity of light.

The formula of Abraham also was founded on assumptions which were speculative. Like Lorentz he assumed a spherical electron at rest but unlike Lorentz made no allowance for change in shape due to motion through the medium, assuming the electron to remain spherical clear up to the velocity of light. While these assumptions were more simple than those of Lorentz, the resulting formula was more complex.

The formula of relativity, which is the same as that of Lorentz, similarly is deduced from assumptions which are speculative. While in the theory of relativity all speculations as to the physical interaction between the moving electron and a medium are abandoned, other assumptions are made which are speculative, removing the phenomena from the world of physics to the intangibles of space and time where they are dealt with in the obscurity of pure mathematics.

Thus far, all theories proposed are founded on assumptions which are admittedly speculative. The only justification for any of the theories lies in their ability to predict results in accord with experiment. None of the theories make any pretense at being in any sense explanations of phenomena but only in leading to formulas convenient in correlating physical data in the same sense that the Balmer and Plank formulas serve as convenient correlations without explanation.

The confirmation of the Lorentz formula by experiment would appear to be a confirmation of the postulates of Lorentz. But since this is the same formula as deduced from the postulates of relativity it may be held equally as a confirmation of these quite different postulates. Thus even an appeal to experiment fails to distinguish between these rival theories.

It is held quite generally that while our theories may at all times be more or less open to question, the results of experiment may be relied on. This confidence in and appeal to experiment is one of the chief distinctions of the present era. This confidence is justified fully when the results sought are capable of direct observation. In complicated cases of the kind here in question the results sought are not amenable to direct observation but must be deduced indirectly by calculation. In the reduction of observed data by calculation some kind of formulas must be used and these in turn depend on some kind of theory. If the theories according to which the data are calculated are speculative the results of the experiment must also be speculative and cannot be relied on.

Thus the results of experiment cannot be relied on unless the theories underlying the experiment can also be relied on.

In the case under consideration it can be shown that the theoretical concepts underlying the experiment are speculative and that the formulas used in the reduction of experimental data are in error and therefore that the experimental results so far obtained are not decisive.

DETERMINATION OF MOTIONAL MASS

The simplest approach to a critical analysis of the experiments confirming the motional mass of the electron is to follow the method used by J. J. Thompson in his first determinations of e/m. Although this is not precisely the method used in making high speed determinations, the underlying principles are the same, the differences being mainly differences in technique.

The physical structure of Thomson's apparatus is substantially that of an ordinary cathode-ray oscilloscope tube. The mode of operation and underlying equations are given in most text books of physics which for the sake of completeness will be repeated here briefly.

Electrons emitted by a cathode K shown in Figure 1 are accelerated by a high potential field between the cathode and anode A. A small orifice in the anode permits a small beam of electrons to continue toward a fluorescent or photographic screen S, passing first through an electric field between a pair of deflecting plates P_1P_2 and a magnetic field at right angles to the electric field.

When no deflecting fields are present, the electron beam follows the straight line BO. When the magnetic field acts alone, the electron stream is bent in the arc of a circle BC within the region of the field, continuing toward the screen in the straight line CD. Under this condition each electron constitutes a current element $[(ev)/c]$ which in passing through the magnetic field H is acted on by a force $H[(ev)/c]$, according to Ampere's law, acting always at right angles to the line of motion. The electron thus moves in the arc of a circle. Equating the radial magnetic accelerating force acting on the electron to the force of electron inertia, that is, centrifugal force, the

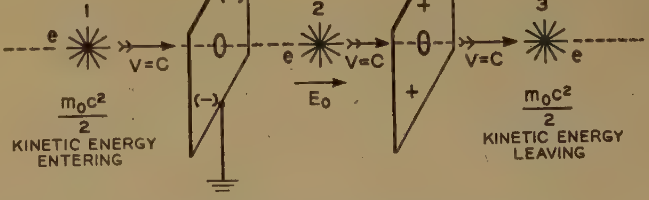


Figure 2. Case of failure of an electron to be accelerated when moving through a potential difference

equation of motion is

$$H[(ev)/c]=m(v^2/r) \tag{5}$$

where

e = electronic charge in statcoulombs
m = electronic mass in grams
r = radius of orbit in centimeters
H = magnetic field strength in gausses

Solving equation 5 for e/m we have

$$\frac{e}{m}=\frac{c}{r}\times\frac{v}{H} \tag{6}$$

The value of r is obtained from the measured deflection of the spot on the screen and the geometry of the apparatus.

The value of v is obtained by exciting the electric deflecting plates P_1P_2 by a field just sufficient to bring the spot back to the origin 0. Under this condition the pull of the electric field on the electron just balances the magnetic deflecting force and we write

$$Ee=H[(ev)/c] \tag{7}$$

where E is the electric intensity between the plates in statvolts. Solving for v we have

$$v=c(E/H) \tag{8}$$

Substituting this value of v in equation 6 we have finally

$$\frac{e}{m}=\frac{c^2}{r}\times\frac{E}{H^2} \tag{9}$$

The value of e/m thus may be determined by substituting the experimentally determined values of E, H, and r in equation 9.

In making high speed determinations, the technique differs mainly in using radium as a source of electrons and in bringing the deflecting plates very close together, separations of 0.5 to 1.0 millimeter being common together with plate lengths of 2 to 6 centimeters. With this arrangement electrons of only one velocity can pass between the deflecting plates. By altering the value of E electrons of another velocity are passed. The electrons also are deflected in a magnetic field either before or after passing between the plates. Thus as before the velocity is determined by equation 8 and the value of e/m by equation 6. Because of the small emission from radium, a photographic film must be used instead of a fluorescent screen, and a long exposure is required.

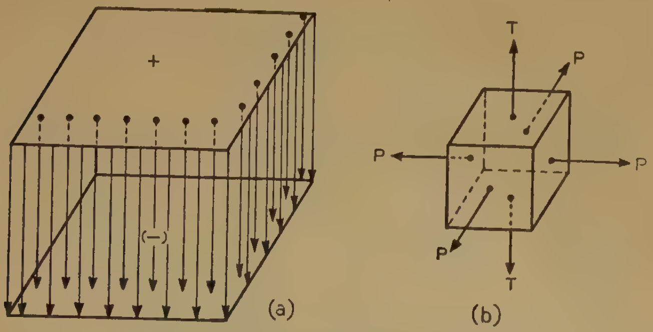


Figure 3. Properties of an electric field

The values of e/m obtained in this way are found to vary with velocity. This variation might be attributed to a variation in either charge or mass or to some error in the method. Since the validity of the method, as laid down in the equations, has never been questioned, and since there is nothing in contemporary theory to suggest a change in charge, the variations observed have been attributed to a change in mass. Since the values of e/m decrease with velocity, it is concluded that the mass must increase. The results thus obtained conform to the formula of Lorentz with accuracy up to 70 or 80 per cent of the velocity of light.

DEFECTS OF CLASSICAL THEORY

A closer examination of equation 7 however shows it to be defective. The mechanical pull on the electron e moving at high speed through the static field E is taken to be Ee just as if the electron were at rest. No allowance is made for the effect of relative motion of electron e through field E.

It long has been held by both classical theory and relativity theory that an electric field in motion is increased in intensity according to a formula exactly analogous to the motional formula of Lorentz for electronic mass, that is

$$E_v=\frac{E_0}{\sqrt{1-(v^2/c^2)}} \tag{10}$$

where

E_0 = the intensity of an electric field at rest
E_v = the intensity of the field E_0 moving at velocity v

Since, according to relativity, it is only relative motion that counts, this equation applies equally to the case where the field is at rest and the test charge such as an electron is in motion. The denominator of this equation is in the nature of a correction factor to correct the static field effect for relative motion.

Thus the pull on the moving electron is given by

$$F=\frac{E_0e}{\sqrt{1-(v^2/c^2)}} \tag{11}$$

which is the value which should have been used in equation 7 instead of Ee.

After substituting this value equation 8 becomes

$$v=c\,\frac{[E/\sqrt{1-(v^2/c^2)}]}{H} \tag{12}$$

and equation 9 becomes

$$e/m=\frac{c^2}{r}\,\frac{[E/\sqrt{1-(v^2/c^2)}]}{H^2} \tag{13}$$

Now in calculating the data derived from experiment, Kaufmann, Bucherer, Neumann, and others all used formula 9 or a corresponding equivalent, which makes no allowance for relative motion of the electron in the deflecting electric field, whereas they should have used equation 13 which does make such an allowance.

If their data are recalculated on the basis of equation 13, their value of e/m will come out a constant instead of a variable which means that the mass of an electron is a constant and independent of velocity.

This of course is a complete reversal of present views.

That this is so may be seen by transposing the radical in equation 13 to the left hand side where it becomes

$$\frac{e}{m/\sqrt{1-(v^2/c^2)}}=\frac{c^2}{r}\times\frac{E}{H^2} \tag{14}$$

which is in the form of equation 9.

Now since the experimental data calculated on the basis of equation 9 yield values of m in accord with the formula of Lorentz

$$m_v=\frac{m_0}{\sqrt{1-(v^2/c^2)}} \tag{1}$$

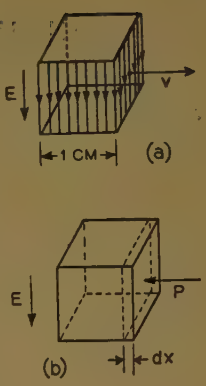
it is evident that the m of equation 14 which is also the m of equation 13 must be the m_0 of equation 1 and therefore a constant, since m_0 is the rest mass.

It is now clear that the variation in mass of the electron derived from experiment arises from a defect in the theory on which the experiments were based. The variation which was observed and attributed to variation in mass, actually turns out to be the variation in mechanical pull on the electron moving in a stationary electric field formerly thought to be constant and independent of motion. What has been determined by experiment then, is not the law of increase in mass with velocity, but the law of increase in mechanical pull due to the relative motion of an electron in an electric field. The experimental data are still valid. It is the interpretation that needs revision.

CORRECT INTERPRETATION OF DATA

Experiment then has demonstrated not the validity of the Lorentz motional-mass equation 1 but the validity of the motional field equation 10 applied as in equation 11.

It must not be overlooked that the complete validity of the motional field equation 10 has not been established except for the ranges tested. The difficulties encountered in the high velocity regions are such as to leave that question still open. Bucherer found that for velocities exceeding 80 per cent of the velocity of light "it was impossible to obtain sharp traces because of the spreading of the photographic line." Neumann after repeating Bucherer's experiment with great care stated that for velocities less than 70 per cent of light, agreement with the relativity theory was satisfactory. But for velocities greater than 70 per cent the data showed a trend away from the theory. More recent experiments have not succeeded in clearing up this question. Even in the low velocity regions the efforts toward higher accuracy have uncovered new sources of error such as polarization effects on the metal surfaces by Stewart and aperture or slit effect by Shaw.



Mechanical mass of electric field. The lateral mass in the direction v is $m=\frac{E^2}{8\pi}\times\frac{2}{c^2}$ *grams per cubic centimeter*

Lateral elasticity of an electric field is $\frac{dP}{dx}=2P=2\frac{E^2}{8\pi}$. *Compressive deformation dx requires pressure increment dP*

Figure 4. Properties of an electric field

Something needs to be said to clarify statements made in connection with motional field equation 10. The foregoing interpretation is that put forward by relativity and by classical theory. While the equation itself within the ranges tested and when applied specifically as in equation 11 is accepted here as valid, the underlying physical concepts as commonly put forward are not accepted. That is, the view that an electric field E_0 moving through space at velocity v is increased physically by the motion to a new value E_v is denied. It is conceded however that the moving field acts on a stationary test electron as if a stationary field E_v were acting, which is quite a different thing than to suppose the field itself increased by reason of its motion.

A sharp distinction must be made between the physical fields themselves and what is measured; that is what is measured by a test charge placed in a moving electric field. It sometimes is stated that what is measured is real. But what is measured, and what a thing is, may be very different, depending on what happens during the process of measurement. It is customary to state that an electric field is measured by the pull on an idealized unit test charge placed in the field, without regard to any motion that may exist. Now something does happen during the process of measurement when there is relative motion between the field and the test charge. The field of the test charge is a physical entity possessing both elasticity and inertia. When this field is combined with another field also possessing elasticity and inertia the resultant field when at rest obviously must be different than when in relative motion since it takes time for an inertial and elastic system to readjust itself. It is therefore incorrect to place a test charge such as an electron in a moving electric field, measure the pull, and then say that that is the strength of the field.

The importance of sharp distinctions, founded if possible on some sort of physical concept, rather than trusting wholly to mathematical guidance hardly can be

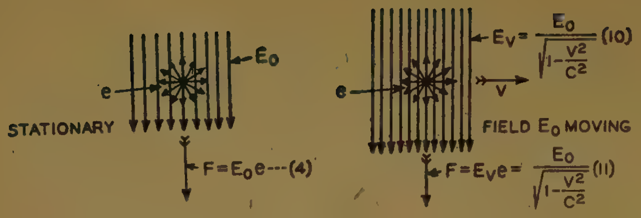


Figure 5

The interpretation of equation 10 to mean that E_0 is increased physically to E_v by motion is denied. It is concurred that the stationary charge e in a moving field E_0 is acted on by a force $F=E_ve$. The increased pull is attributed to the inertial reaction between e and E_0 and not to an increase in E_0

overstated. The failure to be so guided has led to another error of the same kind as that already pointed out, or, more accurately, another aspect of the same question, namely, the failure to recognize the need for applying some kind of motional factor in the case where the electron falls along the lines of force of the accelerating field.

In the former case the electron moves laterally, that is across the lines of force. Here difficulties arose from making no allowance for the motional interaction of the inertial and elastic fields. Because of this omission we were led to believe that the mass of the electron increased with motion.

In this case however, we come into conflict with the law of conservation of energy, for we are led to suppose that the electron in falling through a potential V acquires kinetic energy Ve according to equation 2. No one now questions the accuracy of this conclusion because here again it is assumed (as though it were axiomatic) that the static field equation 4 can be relied on to give correctly the instantaneous accelerating force acting on the moving electron. If this were so, the validity of equation 2 would follow immediately.

If, however, we are guided by physical, as well as mathematical concepts, we see that there must be a definite falling off in the effective accelerating force acting on the electron from instant to instant as it gains speed. That this must be so, follows from the recognition of the inertial and elastic nature of the field which therefore takes time to readjust itself around the fast moving electron. Clearly the motional field distribution must be different from the static case and therefore the static field equation 4 cannot apply. We see by simple inspection that, because of its inertia, the accelerating field does not have time to close in fully behind the fast moving electron, leaving a sort of electric vacuum behind the electron, into which, because of its low field pressure, the field of the electron spreads and thus, by reshaping the field, partially balances or reduces the effective force acting to accelerate the electron. This falling off in the active accelerating force increases with velocity, until finally at the speed of light, the accelerating field fails competely to follow up the electron and the effective accelerating force falls to zero.

Thus an electron in an accelerating field reaches a limiting velocity because the mechanical force effective in accelerating the electron gradually falls to zero owing to the inertia inherent in the accelerating field. When the condition of zero force is reached, acceleration stops and the accelerating field loses completely its ability to give energy to the fast moving electron. This limiting velocity is reached at the propagation velocity of the field, which is the velocity of light.

Thus we find that an electron falling freely through an electric field having a potential difference V acquires a kinetic energy much less than the value Ve expected by contemporary theory since the integral of force × distance is less.

This difference between actual energy acquired and expected energy becomes very great, for very high potentials. In fact practically nothing is gained by using potentials exceeding 2,000,000 volts which brings the electron velocity up to 98 per cent of the velocity of light. At this high velocity the effective accelerating force drops to 0.788 per cent of normal and the kinetic energy acquired in falling through so great a potential is only that corresponding to a fall through 245,000 volts. The limiting kinetic energy possible is only that corresponding to a fall through a potential of 255,000 volts in an idealized field having no inertia and therefore a field having an infinite velocity of propagation which is what is required to satisfy static field equation 4.

We thus see that there is a wide discrepancy between the kinetic energy actually acquired by an electron falling through a high potential field and that expected by contemporary theory and that it is quite meaningless to speak of electron kinetic energies in terms of millions of electron volts as is now customary.

If, for example, we consider the case where an electron already moving at the speed of light is directed through holes in a pair of parallel plates as shown in Figure 2 having a potential difference V so as to accelerate the electron, no kinetic energy whatever is added to the electron. Thus the law of conservation of energy has the appearance of being violated since the electron drops through a potential V without receiving any of the kinetic energy Ve ordinarily expected.

The explanation offered by contemporary theory for this case and for the existence of a limiting velocity which cannot be exceeded, is that at the velocity of light the motional mass of the electron becomes infinite, according to the formula of Lorentz, and that an electron falling through an accelerating potential V at the velocity of light, although still receiving its full quota of energy Ve, cannot have its velocity increased since its kinetic energy is already infinite.

But since we have seen that the mass of an electron in uniform motion remains constant, just as if it were moving in empty space, the explanation advanced by contemporary theory, which takes no notice of the inertial motional field interactions, must be abandoned.

THE EINSTEIN EQUATION

This brings us to a consideration of the Einstein equation 3 which deals with the case of an electron falling through a potential V such as we have been discussing. According to this equation the kinetic energy acquired in the fall is Ve. The equation gives a relation between kinetic energy and velocity acquired. If v be made equal to c the equation makes the kinetic energy Ve infinite. It thus asserts that the limiting possible velocity of an electron is the velocity of light.

The numerical values of potential and corresponding electron velocity given by the Einstein equation are of the order which reasonably may be expected and as we have seen these values are in accord with the results of experiment up to the moderate potentials tested. Its accuracy at high potentials never has been verified. The equation was derived originally by methods based on the assumed validity of the Lorentz equation which as we have seen is unsupportable. While the present interpretation of the Einstein equation must be revised, it is possible that the equation itself may be valid, regardless of its method of derivation; that is, it yields numerical values of potentials and resulting electron velocities in agreement with experiment so far as tested.

The essential numerical validity of the Einstein equation therefore will be assumed tentatively in the light of experiment and without regard to the method by which it originally was deduced; but the physical interpretation of these numerical results will be altered appreciably in view of the principles already laid down.

It will be shown presently that the Einstein equation may be derived on the basis of the mechanical principles of the electric field already roughly pointed out, which might be called the method of field mechanics; a method which so far has received no attention. Before proceeding with the derivation of the Einstein equation, a brief outline of some of the underlying concepts of the new method, which so far have been indicated only qualitatively, will be given.

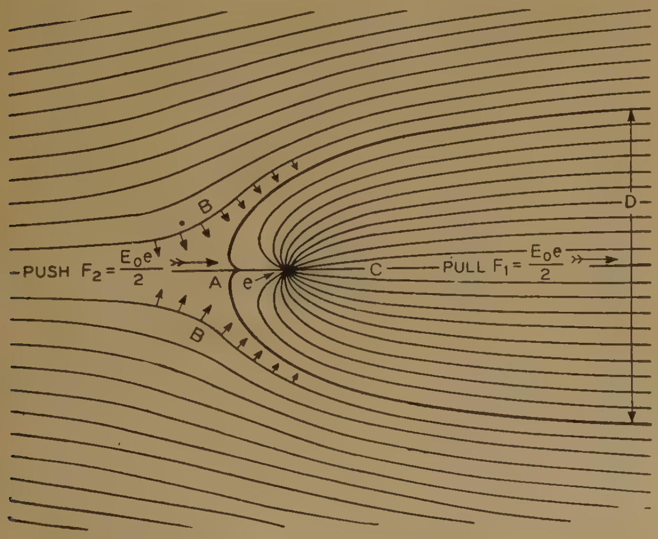


Figure 6. Resultant field around a charge at rest

PROPERTIES OF ELECTRIC FIELDS

The basic mechanical concept of the electric field as set forth by Maxwell is indicated roughly in Figure 3 where the electric field between a pair of charged parallel plates in terms of lines of force, or more accurately tubes of flux, is indicated in Figure 3*a*. In Figure 3*b* is indicated a single cubic centimeter of the idealized field. In the theory of electrostatics it is shown that the mechanical tension in the direction of the field is given by

$$T=\frac{E^2}{8\pi} \text{ dynes per square centimeter} \qquad (15)$$

According to Maxwell this field also exerts an outward pressure P on each lateral face of the cube, analogous to hydraulic pressure and is numerically equal to the longitudinal tension T thus

$$P=\frac{E^2}{8\pi} \text{ dynes per square centimeter} \qquad (16)$$

It also is shown in electrostatics that the field possesses energy in the amount

$$W=\frac{E^2}{8\pi} \text{ ergs per cubic centimeter} \qquad (17)$$

These facts are deducible from experiment by the principles of mechanics. No explanation or analogy is offered, in fact no analogy is possible in terms of gross matter such as solids, liquids, or gases and none should be attempted. Electric field as we shall see is a basic physical entity in itself.

In addition to these well-known properties, the electric field has other properties not well known. The first of these little known properties is that electric field is a physical entity possessing inertia. That is it has mechanical mass subject to Newton's laws of motion in a direction at right angles to its tension. It has no mass in the direction of tension. The amount of this mechanical mass as indicated in Figure 4a is

$$m=\left[\frac{E^2}{8\pi}\times\frac{2}{c^2}\right] \text{ grams per cubic centimeter} \qquad (18)$$

This result is deduced easily directly from ordinary electromagnetic theory (Appendix I). It also may be deduced directly from Einstein's well-known equation between mass and energy

$$\text{Energy}=mc^2$$

by substituting the energy of a cubic centimeter of electric field as given in equation 17 and dividing by c^2. It would be better however to derive Einstein's mass–energy equation from electromagnetic equation 18 as being more fundamental (Appendix III).

The presence of the 2 in equation 18 should be noted, which is not present if the equation is derived from Ein-

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stein's mass–energy equation. The reason for this is that the mass of the electric field is directional and Einstein's equation, applying to mass in general (where the fields are in all directions), is the mean square value of the more fundamental field–mass equation 18.

The validity of field–mass equation 18 also can be shown by integrating the mass of the radial electric field in the space around the electronic nucleus, the result of which comes out identically with the formula obtained by J. J. Thomson for the mass of the electron (Appendix IV). The method however is more direct than that of Thomson in that the mass is attributed directly to the electric field itself, rather than indirectly to a magnetic field distributed according to the law of Ampere and generated by motion. From this and other investigations it appears that magnetism is numerically equal to the kinetic energy of the electric field and is not a fundamental entity in itself as generally supposed but rather a motional aspect of electric field.

This view of the fundamental validity of field–mass equation 18 also is supported by comparison with many other electromagnetic equations where it yields many interesting results and helps greatly in clarification.

A second property of the electric field which seems not to have been recognized at all heretofore is that it possesses lateral elasticity in the true mechanical sense. Electric field long has been considered to have longitudinal elasticity, that is in the direction of its tension, but this kind of elasticity has been shown to be a pseudo elasticity, not conforming to the definition of mechanical elasticity, and therefore is denied. But, in a lateral direction, it can be shown to possess true mechanical elasticity (Appendix II).

Figure 4 indicates an idealized cubic centimeter of electric field with tensions and pressures as in Figure 3. The normal outward pressure P due to the field content within the geometric cube of reference is balanced by the equal inward pressure P of the adjacent field pressing against and confining that within the cube. If we imagine an electrical piston (such as adjacent electric field) to compress the contents of the cubic centimeter by a deformation dx, it can be shown that the pressure P will increase by an amount dP which can be calculated by the theory of electrostatics. If this increased pressure dP is divided by the deformation dx we get a result which is the true mechanical elasticity of the electric field.

The result comes out

$$\text{Mechanical elasticity} = \frac{\text{increment in stress}}{\text{deformation}}$$

$$= \frac{dP}{dx}$$

$$= 2\frac{E^2}{8\pi}$$

$$= 2p \qquad (19)$$

This result is closely analogous to the mechanical elasticity of a gas and is calculated by precisely the same method. In the case of a gas the mechanical elasticity comes out P whereas in the case of electric field the elasticity is $2P$. In its lateral aspect therefore electric field is exactly analogous to a gas except no temperature effects are involved.

If we substitute the foregoing values of elasticity and mass in the formula for the velocity of propagation in a mechanical medium,

$$v = \sqrt{\frac{\text{elasticity}}{\text{density}}}$$

we have

$$= \sqrt{\frac{2\frac{E^2}{8\pi}}{\frac{E^2}{8\pi}\times\frac{2}{c^2}}}$$

$$= c = \text{the velocity of light} \qquad (20)$$

This equation, which involves only the purely mechanical properties of the electric field shows that the electric field is itself a medium of propagation in the purely mechanical sense and gives a value in agreement with the known result of experiment. It is to be noted that the velocity of propagation is independent of the electrical intensity, being analogous to propagation in a gas which is independent of pressure. It is also to be noted that there is nothing magnetic in this equation. The equation is of more than passing interest as it gives a new insight into the nature of medium, the Michelson Morley experiment, relativity, and other questions not yet cleared up.

The foregoing very brief outline of the demonstrable inertial and elastic properties of the eléctric field should be sufficient to justify the viewpoint taken in the preceding qualitative discussion and to support the treatment which follows.

FORCES ON MOVING ELECTRONS

To return now to the question of the motion of an electron along the lines of force of an electric field, Figure 6 shows a conventional plot of the resultant field around a charge at rest. The force acting on the charge is due to the tension of the field terminating on the charge. This force, however, in regions some distance from the nucleus is resolved physically into two equal components; a pull $F_1 = E_0e/2$ due to tension in the region C, and a push $F_2 = E_0e/2$ in the region A, due to side pressure from the main field in the region B. The function of the main field E_0 is to compress the electron flux within the surface of revolution D, thereby increasing its tension, and to supply the compressive push at A.

In Figure 7 is shown an approximate plot of the field distribution around a moving charge. Here we find the electron e moving out of the region A faster then the field in the region B can close in and fill up the space previously occupied by the field of the electron. This lag of the main field is due to its lateral inertia as previously discussed. Since the compressive pressure of the main field on the electronic field is reduced, the electronic field, relieved of restraint, spreads out into the region of reduced lateral pressure A and thus becomes more nearly radial. The net result is less resultant mechanical force acting to accelerate the electron and the simple formula equation 4 no longer applies.

As the electron velocity increases, the region of low field pressure A increases and the radial spread of the electron field increases. Thus the net force effective in accelerating the electron falls off progressively as the speed increases, becoming zero at the speed of light as previously mentioned.

Clearly then the accelerating force must fall off as some function of the electron velocity, approaching zero as a limit at the velocity of light and satisfying static field equation 4 at rest. Equation 4 therefore must be modified by a motional factor satisfying these known terminal conditions and conforming to whatever other data are available. The force equation then will be of the form

$$F=E_0[f(v)]e \tag{21}$$

The problem now is to find the motional function $f(v)$. Rather than attempt a direct solution of the inertial and elastic field complex itself, it is easier to find a function which will fit some already existing equation which is known to be valid at least in part, and has some reasonable hope for final validity. We find just such an expression in Einstein's equation. It conforms to the initial and final conditions which we see by inspection must be satisfied. It is a continuous function connecting potential and velocity in a reasonable manner and in conformity with experiment so far as tested. We therefore will assume tentatively that a motional function $f(v)$ which is of such form that, when applied to the problem of an electron accelerated in a uniform electric field in conformity with the ordinary laws of mechanics it yields as a result Einstein's equation, then that function is the proper one to satisfy equation 21.

Such a function has been found to be

$$f(v)=[1-(v^2/c^2)]^{3/2} \tag{22}$$

We therefore may write

$$E_{\text{eff}}=E_0[1-(v^2/c^2)]^{3/2} \tag{23}$$

where E_{eff} is the effective field acting on the moving electron at velocity v. That is, it is a static field which acting on the charge e at rest, produces the same force as that exerted by the static field E_0 on the moving electron. $E_{\text{eff}}=E_0$ when the electron is at rest, and equation 4 is satisfied. When $v=c$, $E_{\text{eff}}=0$, as it should. Writing this in the form of equation 21 we have

$$\begin{aligned} E&=F_{\text{eff}}e\\ &=E_0[1-(v^2/c^2)]^{3/2}e \end{aligned} \tag{24}$$

Applying this to the motion of an electron in a uniform

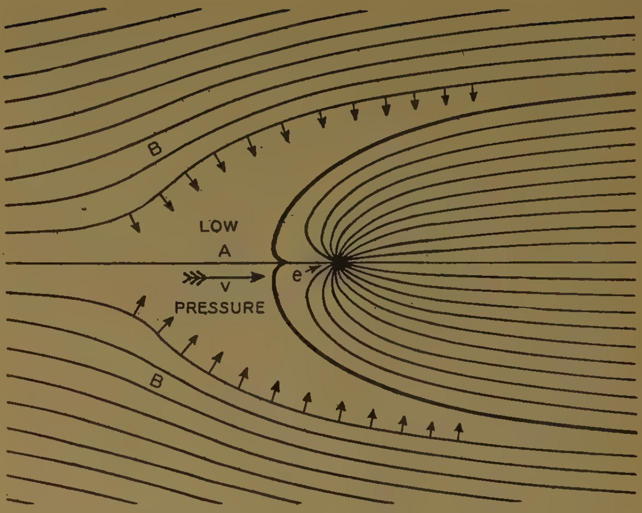


Figure 7. Field distribution around a moving charge

electric field of intensity E_0, assuming the validity of Newton's laws and the ordinary principles of mechanics,

$$\begin{aligned} F&=\frac{d}{dt}[mv]\\ &=m_0\frac{dv}{dt} \end{aligned} \tag{25}$$

$F=$ mass × acceleration

since from the foregoing $m_v=m_0$, a constant for all velocities. The work done on the moving electron conforms to

$W=$ force × distance

$$\begin{aligned} dW&=Fdx\\ &=E_{\text{eff}}edx\\ dW&=E_0e[1-(v^2/c^2)]^{3/2}dx\\ &=\left[m_0\frac{dv}{dt}\right]dx \end{aligned} \tag{26}$$

Now for the element of distance dx we may write

$$dx=v\,dt$$

Substituting this value of dx in right hand member of equation 26 we have

$$E_0e[1-(v^2/c^2)]^{3/2}dx=m_0vdv \tag{27}$$

Solve for dx

$$dx=\frac{m_0}{E_0e}\times\frac{vdv}{[1-(v^2/c^2)]^{3/2}} \tag{28}$$

$$\begin{aligned} x&=\frac{m_0}{E_0e}\int_0^v\frac{vdv}{[1-(v^2/c^2)]^{3/2}}\\ &=\frac{m_0c^2}{E_0e}\left[\frac{1}{\sqrt{1-(v^2/c^2)}}-1\right] \end{aligned} \tag{29}$$

Multiplying through by E_0e, we get

$$\begin{aligned} [E_0x]e&=Ve\\ &=m_0c^2\left[\frac{1}{\sqrt{1-(v^2/c^2)}}-1\right] \end{aligned} \tag{30}$$

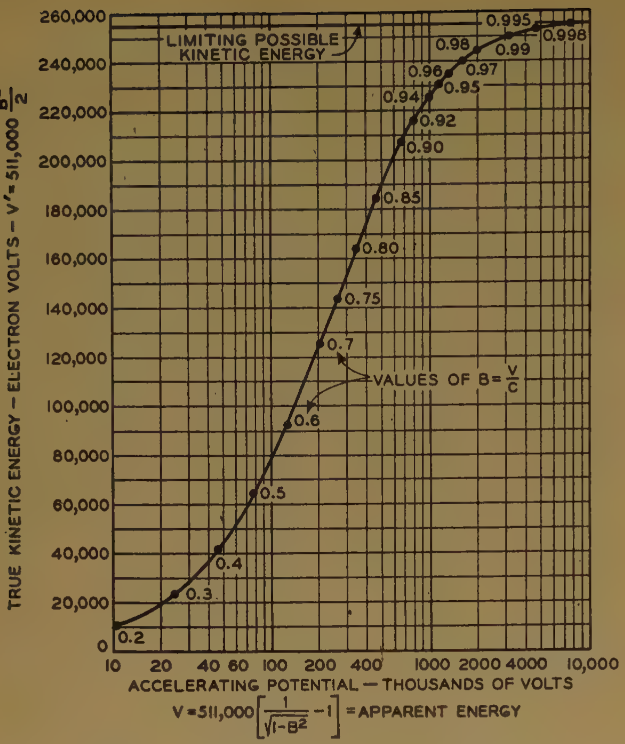


Figure 8. Plot of columns 3 and 4 of Table I

where $V = E_0 x$, the potential through which the electron falls.

This result will be recognized immediately by comparison with equation 3 as Einstein's equation.

We thus have been able to derive Einstein's equation, originally deduced by the abstract methods of relativity, by applying only ordinary electrical and mechanical methods and concepts.

We have assumed as a basis, only the numerical validity of the Einstein equation. If this be granted, the validity of motional field equation 24 follows immediately.

If the validity of motional field equation 24 is granted, the whole underlying physical theory given in the foregoing is verified.

Thus the validity of the Einstein equation as a result in itself is sustained, although the original underlying concepts and mode of derivation are abandoned. The interpretation of the equation, in the light of the foregoing derivation and the principles on which it is founded, must be altered appreciably.

ELECTRON ENERGY

Since the electronic mass has been shown to be a constant for all velocities, the kinetic energy of the electron computed for velocities given by the Einstein equation is very much less than the value Ve expected by contemporary theory. There is thus an apparent violation of the law of conservation of energy.

This violation however is only apparent since the usual method of computing the energy acquired in falling through the field leaves out of consideration the fact that the accelerating force falls off with increase of velocity and therefore the true acquired kinetic energy cannot be calculated as the product of potential×charge.

The product Ve is what might be called apparent energy by analogy with the product EI called apparent power in an a-c system. To get true energy we must multiply Ve by a proper factor just as we multiply apparent power EI by a factor (the power factor) to get true power.

The value of this energy factor is

$$\frac{V'}{V} = \frac{\text{actual energy}}{\text{apparent energy}}$$

$$= \frac{1}{2}\left[\frac{\beta^2}{\dfrac{1}{\sqrt{1-\beta^2}} - 1}\right] \tag{31}$$

where

$\beta = v/c$

This is derived as follows. Assume a new potential V' applying to a fictitious electric field having an infinite velocity of propagation and therefore not subject to the motional factor of equation 22. An electron falling through the potential V' in such a field would acquire the kinetic energy Ve exactly, and we may write

$$V'e = m(v^2/2) \tag{32}$$

The right hand member gives the true kinetic energy of the electron at velocity v and thus the value of the fictitious potential V' is determined.

The actual potential required to produce the velocity

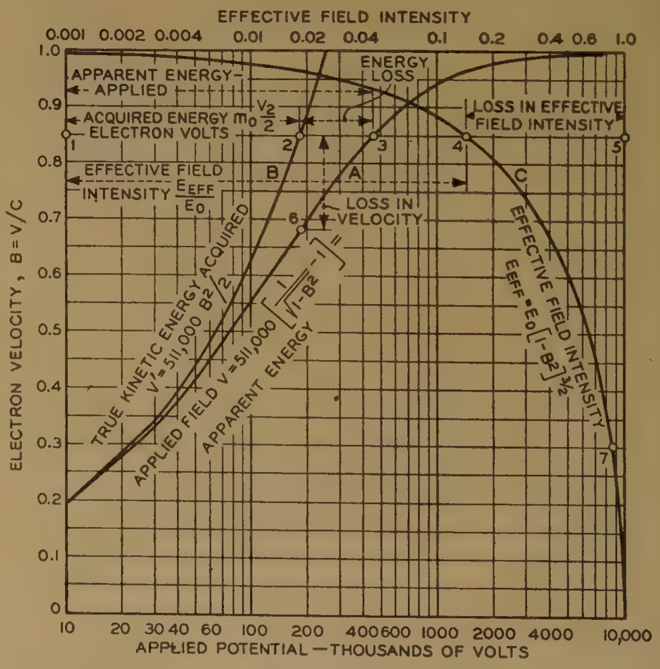


Figure 9. Plot of column 1 versus columns 3, 4, and 6 of Table I

v is given by Einstein's equation, thus

$$\text{Apparent energy} = Ve$$
$$= m_0c^2\left[\frac{1}{\sqrt{1-(v^2/c^2)}}-1\right] \tag{30}$$

$$\text{Energy factor} = \frac{\text{actual energy}}{\text{apparent energy}}$$
$$= \frac{V'e}{Ve}$$
$$= \frac{m_0v^2/2}{m_0c^2\left[\frac{1}{\sqrt{1-(v^2/c^2)}}-1\right]}$$
$$= \frac{1}{2}\frac{\beta^2}{\left[\frac{1}{\sqrt{1-\beta^2}}-1\right]} \tag{31}$$

In computing the true kinetic energy of an electron, the known potential through which it falls must be multiplied by this factor.

The equations so far have all been in electrostatic units.

By expressing V in volts and taking the known values as

$e = 4.774 \times 10^{-10}$ statcoulombs
$m = 9.04 \times 10^{-28}$ grams
$c = 3 \times 10^{10}$ centimeters per second

the apparent kinetic energy calculated by Einstein's equation in electron volts becomes

$$V = \frac{m_0c^2}{e} \times 300\left[\frac{1}{\sqrt{1-\beta^2}}-1\right]$$
$$= 511{,}000\left[\frac{1}{\sqrt{1-\beta^2}}-1\right] \tag{33}$$

Similarly the true energy from equation 32 becomes

$$\frac{V'e}{300} = \frac{m_0v^2}{2}$$
$$= m_0c^2\left[\frac{1}{2}\frac{v^2}{c^2}\right]$$
$$= m_0c^2 \times \frac{1}{2}\beta^2$$
$$V' = 511{,}000\left[\frac{\beta^2}{2}\right] \tag{34}$$

Equation 34 gives the true kinetic energy in electron volts of an electron moving at velocity $\beta = v/c$ regardless of the manner in which this velocity is acquired. This velocity might be acquired, theoretically, in an idealized inertialess field of potential V', that is, in the kind of electric field ordinarily contemplated, which leaves out of consideration the idea of field inertia. But, while the potential V' correctly measures the kinetic energy of a real electron which somehow has acquired the velocity β, this potential is insufficient to produce the velocity β in a real field having inertia.

It has been shown that Einstein's equation applies to real fields possessing inertia since in its derivation it contains an allowance for field inertia as given by equation 23. To calculate the potential which must be applied to produce the velocity β in a real field having inertia, Einstein's equation must be used. This potential is always greater than V' giving the kinetic energy acquired. The difference between V and V' gives the excess potential which must be applied in a real field to produce the velocity β owing to the inertial lag in the accelerating field. This difference also gives the apparent energy loss due to field inertia.

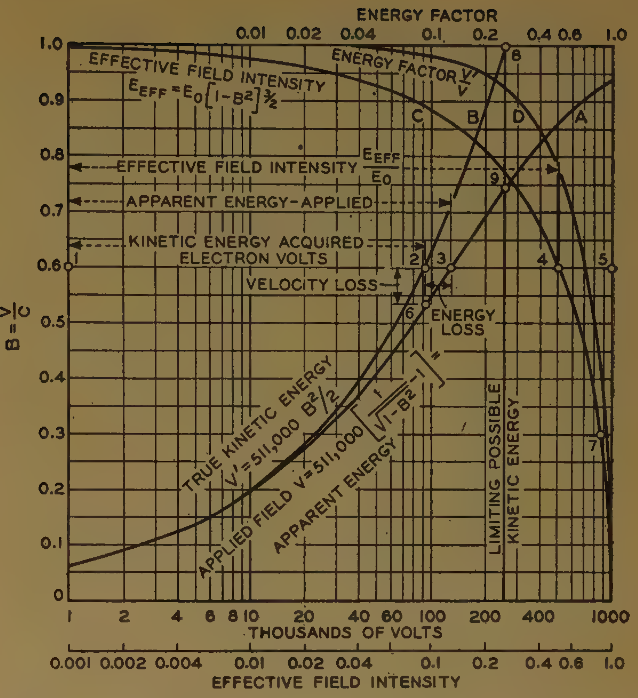


Figure 10. Plot of column 1 versus columns 3, 4, 5, and 6 of Table I

The range of potentials and velocities of this figure is lower than that of Figure 9

While contemporary theory correctly calculates the potential necessary to produce an electronic velocity β by using Einstein's equation, it attributes this increase in required potential to an increase in electron inertia; whereas as has been shown, the effect is really due to an increase in the inertial lag of the accelerating field. Thus an effect attributed to electron inertia has been mistaken for an effect due to field inertia.

The difference in interpretation is considerable, for while the present analysis and contemporary theory agree on the method of calculating the electronic velocity, contemporary theory is led to suppose that mass is increased by motion and that the electron, although moving slower than expected, contains the full amount of field energy Ve, accounted for on the basis of the increased mass. But as has been shown, the mass does not increase and the electron contains much less kinetic energy than Ve because of the inability of the accelerating field to follow up and there is an apparent loss of energy.

NUMERICAL COMPARISONS

To bring out these differences more clearly numerical values given by the foregoing equations have been calculated for a wide range of electron velocities and the results given in Table I. These results have been plotted in curves on semilogarithmic paper.

The velocity factor of Einstein's equation is tabulated in column 2 of Table I.

The values of potential in volts calculated from Einstein's equation are given in column 3. These potentials are the values required to accelerate an electron to the velocity β. These values are considered by contemporary theory to be a measure of the kinetic energy of the electron after falling through the applied potential V.

The true kinetic energy is given in column 4 calculated from equation 34. The discrepancy between the true kinetic energy column 4 and apparent kinetic energy column 3 should be noted carefully. At low velocities these values are in substantial agreement. As velocities increase the discrepancy increases. The true kinetic energy V' reaches a limit of 255,500 electron volts, whereas the apparent kinetic energy approaches infinity.

The values of apparent energy V and true energy V' are plotted in Figure 8. Values of velocity β are given on the curve.

The value of energy factor V'/V is given in column 5.

In column 6 is given the values of the effective field intensity E_{eff} from equation 23. This is the motional function which has been omitted in all previous investigations of the motion of an electron in an electric field. It will be noted that the factor itself is identical with the denominator of Lorentz's equation for longitudinal mass. At low velocities the factor has a value approximately unity and the ordinary laws of electrostatics apply. At high velocities, the value of the motional function becomes appreciable and the error in applying the formula of electrostatics, without correction for relative motion, is very serious. At 99 per cent of the velocity of light, the effective field intensity drops to 0.28 per cent of its value at rest. Even at $\beta=0.1$ there is a falling off of 1.5 per cent, so that at all potentials exceeding say 5,000 volts, serious errors arise from the omission of a correction for motional effect.

In Figure 9 values of apparent energy of the applied field, column 3, and true energy, column 4, are plotted against velocity in curves A and B respectively. The horizontal distance between these two curves gives the energy loss due to field inertia. For example point 2 on curve B at 85 per cent of the velocity of light gives the true kinetic energy, Table I, column 4, as 184,600 volts. Point 3 on curve A gives the actual potential required to accelerate an electron to this velocity as 459,070 volts as calculated from Einstein's equation, Table I, column 3. According to contemporary theory the electron at point 3 should have 459,070 electron volts of kinetic energy. But as we have seen from the derivation of the Einstein equation which contains inherently an allowance for the motional inertia of the field, that the electron energy actually acquired is only that given by point 2. There is therefore an apparent energy loss in this case of $[459{,}070-184{,}600]=274{,}470$ electron volts.

The vertical distances between curves A and B in Figure 9 are also significant. These distances give the loss in velocity due to the inability of the field to follow up, owing to its inertia. For example, point 2 on curve B gives the electron velocity as 0.85. This is the velocity an electron would have if it were accelerated by a potential of 184,600 volts in an idealized field having no inertia. The point 6 on curve A gives the actual velocity acquired in a real field of the same potential, as calculated from Einstein's formula. The difference between the velocity at point 2 (with a field having no inertia) and point 6 with a real field having inertia, gives the loss in velocity due to field inertia, in this case $[0.85-0.68]=0.17$. This loss in velocity, attributed by contemporary theory to an increase in electronic inertia, is seen here to be due to a decrease in effectiveness due to field inertia. In other words the effect as pointed out is due to the field inertia instead of electron inertia.

Curve C of Figure 9 is a plot of the effective field intensity E_{eff} of column 6, the field intensities being plotted horizontally against the corresponding velocities vertically. At zero velocity the effective field intensity is unity. At $B=0.85$ the value of E_{eff} has fallen to 0.1462 indicated by point 4 on curve C. The length 1–4 represents the actual field intensity effective in accelerating the electron, while the distance 4–5 represents

Table I

1	2	3	4	5	6
Velocity, $\beta=\frac{v}{c}$	Einstein's Factor, $\left[\frac{1}{\sqrt{1-\beta^2}}-1\right]$	Expected Energy Electron Volts, $V=511{,}000\left[\frac{1}{\sqrt{1-\beta^2}}-1\right]$	Actual Energy Electron Volts, $V'=511{,}000\frac{\beta^2}{2}$	Energy Factor, $\frac{V'}{V}=\frac{\text{Actual}}{\text{Expected}}$	Effective Acceleration Force, $E_{eff}=E_0(1-\beta^2)^{3/2}$
0.1	0.00504	2,575	2,555	0.992064	0.98503×E_0
0.2	0.02063	10,542	10,220	0.969462	0.940580
0.3	0.04830	24,681	22,995	0.931677	0.868076
0.4	0.09108	46,542	40,880	0.878349	0.769890
0.5	0.15470	79,052	63,875	0.808016	0.649515
0.6	0.25000	127,750	91,980	0.720000	0.512000
0.70	0.40028	204,540	125,200	0.612086	0.36421
0.75	0.51192	261,590	143,720	0.549402	0.289342
0.80	0.66674	340,710	163,520	0.479946	0.21600
0.85	0.89836	459,070	184,600	0.402122	0.146172
0.90	1.29430	661,390	206,960	0.312910	0.082613
0.92	1.55167	792,910	216,255	0.271485	0.060190
0.94	1.93163	987,060	225,760	0.228719	0.0396895
0.95	2.20221	1,125,300	230,590	0.204908	0.030454
0.96	2.57140	1,314,000	235,470	0.179202	0.021952
0.97	3.11296	1,590,700	240,273	0.151147	0.014373
0.98	4.02614	2,057,300	245,382	0.119270	0.0078758
0.990	6.09100	3,112,500	250,415	0.080455	0.0028040
0.995	9.01710	4,607,700	252,976	0.054902	0.00099488
0.998	14.8343	7,580,300	255,065	0.033648	0.00025189

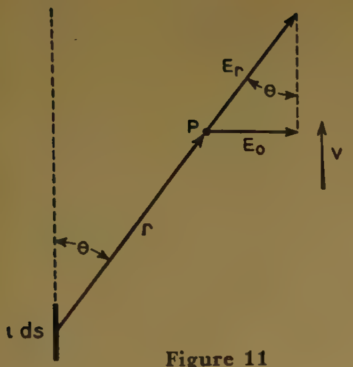


Figure 11

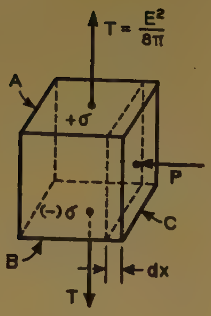


Figure 12

the loss in field intensity due to motion $(1-0.1462)=0.8538$. The distortion of the logarithmic scale obscures the large amount of this motional effect.

In Figure 10 is given a plot similar to Figure 9 except the range of potentials and velocities is lower. The curves *A*, *B*, and *C* correspond to those in Figure 9. In addition the energy factor is plotted as curve *D* from data given in column 5 of Table I. This curve gives the ratio of true energy to apparent energy plotted against corresponding values of β.

The present defects in contemporary theory now should be apparent. It should be noted that while Einstein's equation originally was derived on altogether different grounds, that nevertheless it contains a satisfactory allowance for the motional effect of field inertia. The equation with due interpretation is retained. Einstein's energy–mass equation, now forming so important a part in physics, also is retained, being deducible from ordinary electrical theory. In the revisions indicated in the foregoing, much that has remained in the domain of pure mathematics unsupported by any sort of physical concepts, now is brought within the range of the ordinary concepts of physics and Newtonian mechanics where it may be dealt with in confidence. In short we can again begin to see into the nature of things.

SUMMARY

It has been shown that the present view of the motional mass of the electron is untenable and that the universally accepted formula of Lorentz must be abandoned, together with similar results deduced by the theory of relativity. It has been shown that defects exist in all the theories so far put forward and that these defects in theories have carried over into the confirming experiments, which therefore do not confirm. The defect in all prior theories is the failure to recognize the physical nature of the electric field; in particular that in addition to its well-known properties of longitudinal tension and lateral pressure, it also posesses lateral inertia and lateral elasticity. Owing to these elastic and inertial properties of the field, it has a finite velocity of propagation. The value of the lateral mass of a cubic centimeter of electric field is given, together with the value of lateral elasticity. The square root of the ratio of these values of elasticity to mass is shown to give a velocity of propagation for the electric field identical with the velocity of light.

Since electric field has inertia and elasticity, time is required for all stress readjustments arising from motion, and therefore static field formulas cannot apply with accuracy to cases where an electron and electric field are in relative motion. All prior theory has neglected to take into account these motional effects. It is shown that this neglect has led to the present belief that electron mass increases with velocity. The experimentally observed change in the ratio of charge to mass which has been attributed to change in mass, is shown to be due to a motional effect of the electron in the deflecting electric field which was not recognized heretofore.

When proper allowance is made for this effect of relative motion of an electron in a deflecting electric field, it is shown that the mass of the electron is a constant, independent of velocity, just as it would be if it were moving in idealized empty space.

The Einstein equation giving the relation between applied accelerating potential and the resulting electron velocity is examined. It is shown that while this equation may be numerically accurate, the present interpretation of its results requires revision. It also is shown that the Einstein equation can be derived on the basis of ordinary Newtonian mechanics; making proper allowance for the reduction in pull on the accelerated electron with increase in velocity. This pull is shown to fall from the normal value at rest, given by electrostatics, to zero as a limit at the velocity of light. It is this falling off in pull, due to the inertia of the field, that sets an upper limit to the possible electron velocity which otherwise might increase indefinitely even beyond the velocity of light. This limiting velocity at present is attributed to the increase in electron mass, which at the velocity of light is thought to become infinite.

It is shown that the kinetic energy acquired by an electron accelerated in an electric field is very much less than the product charge×potential; and that for high potentials large corrections must be made. The usual method of calculation gives what may be called apparent energy which must be multiplied by a factor here called energy factor to get true energy. At speeds approaching the velocity of light, the inertia of the accelerating field is so great that the accelerating force becomes very small, approaching zero as a limit. There is therefore no practical advantage gained in applying potentials much in excess of 2,000,000 volts, since there is no appreciable resulting increase in kinetic energy. It is clearly meaningless to speak of electron energies in the order of millions of electron volts.

It is pointed out that Einstein's energy–mass equation is deducible from ordinary electrical theory and like his potential–velocity equation has a validity quite independent of its original method of derivation. Much of the theoretical foundation of modern physics having to

do with the relative motion of an electron in an electric field will require revision. These revisions are constructive and in the nature of simplification and clarification. Only a very brief outline of the method is given as it applies to the specific question under consideration. It has yielded solutions to a number of the still outstanding paradoxes and points the way to the solution of others. It is evident that much light is thrown on the present teachings of the theory of relativity. Much that heretofore has remained in the realm of abstract mathematics now is brought within the range of the ordinary concepts and methods of physics and Newtonian mechanics.

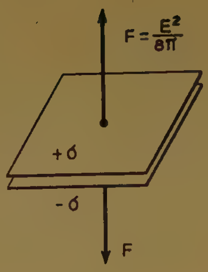


Figure 13

Appendix I

TO SHOW THAT ELECTRIC FIELD HAS A LATERAL MECHANICAL MASS $m=\left[\frac{E^2}{8\pi}\times\frac{2}{c^2}\right]$ GRAMS PER CUBIC CENTIMETER

According to Ampere, a current element *ids* produces a magnetic field H at a point P distant r centimeters from the current element and making an angle θ, with ds as shown in Figure 11.

$$H=\frac{ids}{r^2}\sin\theta \tag{35}$$

For i we may write

$$i=\frac{qv}{c}\text{ absolute amperes} \tag{36}$$

where

q = charge per centimeter statcoulombs
v = velocity in centimeters per second

Substituting this in equation 35 we have

$$\begin{aligned}H&=\left[\frac{qv}{c}\right]\frac{ds}{r^2}\sin\theta\\&=\left[\frac{qds}{r^2}\right]\frac{v}{c}\sin\theta\\&=E_r\sin\theta\,\frac{v}{c}\end{aligned}$$

$$H=E_0\frac{v}{c} \tag{37}$$

where E_0 is the electric field intensity at P resolved at right angles to v. This is the well-known basic relation between E and H.

Squaring both sides of equation 37 and dividing by 8π we have after arranging

$$\frac{H^2}{8\pi}=\left[\frac{E^2}{8\pi}\times\frac{2}{c^2}\right]\frac{v^2}{2} \tag{38}$$

Here we recognize $H^2/(8\pi)$ as the magnetic energy in ergs per cubic centimeter and $E^2/(8\pi)$ as the electric energy per cubic centimeter.

Now according to Maxwell, magnetic energy is kinetic. Wherever we find magnetic field, we always find it to be the consequence of electric charges in motion. That is, magnetism is a kinetic phenomenon arising from the motion of electric field according to equation 37.

Equation 38 is therefore an equation of kinetic energy and we may compare it part by part with the ordinary equation for kinetic energy

$$W=m(v^2/2) \tag{39}$$

On the right we have in each equation a coefficient which multiplied by $v^2/2$ gives kinetic energy. The terms correspond exactly. Therefore we may write

$$W=\frac{H^2}{8\pi} \tag{40}$$

Since the coefficient of $v^2/2$ in equation 39 is mass, it follows that the corresponding coefficient in equation 38 is also mass and so

$$m=\frac{E^2}{8\pi}\times\frac{2}{c^2} \tag{18}$$

Thus magnetic energy is the kinetic energy of a cubic centimeter of electric field whose mass is given by equation 18.

This value of electric mass conforms to all the laws of Newtonian mechanics and may be substituted in any equation, provided it is understood that the inertia or mass acts only at right angles to the tension of the field.

Magnetism is therefore not a basic entity in itself as sometimes supposed but a motional aspect of electric field which is basic.

Appendix II

TO SHOW THAT ELECTRIC FIELD HAS TRUE MECHANICAL ELASTICITY, LATERALLY, WHOSE VALUE IS $Elasticity=2\frac{E^2}{8\pi}=2P$

Consider a cubic centimeter of electric field terminated at top and bottom by metal plates A and B as shown in Figure 12 on which reside charge densities $+\sigma$ and $-\sigma$.

The pull on the plates sustaining the tension of the field is

$$\begin{aligned}T&=2\pi\sigma^2\\&=\frac{E^2}{8\pi}\\&=P\end{aligned} \tag{41}$$

This tension is accompanied by a lateral outward hydraulic pressure P on all faces of the cube and is balanced by the equal inward compressive pressure P of the adjacent field.

Assume an electrical piston acting on the lateral face C to compress the field contents of the cube by an amount dx.

This may be accomplished by increasing the side pressure of the adjacent field, which means an increase in potential between the plates of which A and B form a part. In other words by increasing the potential between plates more charge is forced on the plates and the original charges $+\sigma$ and $-\sigma$ with their associated fields are compressed into a smaller space $[1-dx]$ centimeter.

The new charge density is

$$\begin{aligned}\sigma'&=\frac{\sigma}{1-dx}\\&=\sigma[1+dx]\end{aligned} \tag{42}$$

This compression requires an increase in side pressure dP. The new tension and pressure are

$$\begin{aligned} T' = P' & \\ &= P + dP \\ &= 2\pi\sigma'^2 \\ &= 2\pi\sigma^2[1+dx]^2 \\ &= 2\pi\sigma^2[1+2dx] \end{aligned} \tag{43}$$

$$dP = 2\pi\sigma^2\, 2dx \tag{44}$$

By the definition of elasticity

$$\begin{aligned} \text{Elasticity} &= \frac{\text{stress}}{\text{strain}} \\ &= \frac{\text{increment in pressure per square centimeter}}{\text{deformation per centimeter length}} \end{aligned} \tag{45}$$

Thus

$$\begin{aligned} \text{Elasticity} &= \frac{dP}{dx} \\ &= 2\times 2\pi\sigma^2 \\ &= 2P \\ &= 2\frac{E^2}{8\pi} \end{aligned} \tag{19}$$

Thus electric field is a physical entity having true lateral mechanical elasticity whose numerical value is twice the mechanical field pressure in dynes per square centimeter. In its lateral aspect it is therefore exactly analogous to a perfect gas whose elasticity, calculated by methods similar to the foregoing, is numerically equal to the gas pressure.

Electric field has no elasticity in the direction of its tension, since the field stretches indefinitely without increase in tension so long as the field is kept parallel.

Appendix III

TO SHOW THAT ENERGY AND MASS ARE INTERCONVERTIBLE

$$\text{Energy} = mc^2$$

Consider two metal plates very close together with charges $+\sigma$ and $-\sigma$ per square centimeter as shown in Figure 13. By taking only one square centimeter of the large plates which serve to keep the field parallel, the force of attraction is given by

$$\begin{aligned} F &= 2\pi\sigma^2 \\ &= \frac{E^2}{8\pi} \end{aligned} \tag{46}$$

No energy is stored in the region between the plates since there is no volume.

If we now pull the plates apart one centimeter, the work done is

$$\begin{aligned} W &= \text{force} \times \text{distance} \\ &= F \times 1 \\ &= \frac{E^2}{8\pi}\,\text{ergs} \end{aligned} \tag{17}$$

Now $E^2/(8\pi)$ergs of mechanical energy have disappeared and we have brought into being a cubic centimeter of electric field which did not exist before. This cubic centimeter of field as we have seen has mass $\frac{E^2}{8\pi}\times\frac{2}{c^2}$.

We therefore have converted $E^2/(8\pi)$ ergs of mechanical energy into $\frac{E^2}{8\pi}\times\frac{2}{c^2}$ grams of mechanical mass. That is, we have transformed energy into matter and in that sense have created matter. This kind of matter differs from ordinary matter only in not being locked permanently in position. That is, it is matter in an unstable form and will disappear in radiation or equivalent energy, unless prevented. The mass of an electron and proton is essentially the same, except the system is radial, and nature has found a way of uniting or locking up the stresses at the focal center which prevents the mass disappearing spontaneously in the form of radiation. Radiation in this sense is a radiation of matter.

The conversion factor for the transformation of energy into matter or the reverse is derived as follows.

Energy expended = mass created × conversion factor

$$\frac{E^2}{8\pi} = \left[\frac{E^2}{8\pi}\times\frac{2}{c^2}\right]\times\text{conversion factor} \tag{47}$$

By inspection the conversion factor is seen to be $c^2/2$. Hence we may write

$$\text{Energy} = \text{mass} \times (c^2/2) \tag{48}$$

This is Einstein's energy–mass relation originally arrived at by relativity. This derivation is more fundamental than Einstein's, since it applies to electric field in its elemental state, which is the basis of all mass. For field whose direction averages through 360 degrees we take the mean square value which is 1/2. That is, the average mass is only 1/2 the above value or

$$\text{Energy} = mc^2$$

which is Einstein's equation exactly.

Appendix IV

CALCULATION OF ELECTRONIC MASS BY DIRECT INTEGRATION OF ELECTRIC FIELD DENSITY

$$m = \left[\frac{E^2}{8\pi}\times\frac{2}{c^2}\right]$$

Let q be a charge confined to the surface of a sphere of radius a in motion along the axis OX as shown in Figure 14.

Consider the annular element of volume dv, having a radius $(r\sin\theta)$ and cross section $(r\,d\theta\,dr)$.

The electrical mass of this element of volume is given by

$$\begin{aligned} dm &= \left[\frac{E^2}{8\pi}\times\frac{2}{c^2}\right]dv \\ &= \left[\frac{E^2}{8\pi}\times\frac{2}{c^2}\right]rd\theta dr 2\pi r\sin\theta \end{aligned} \tag{49}$$

The electric field intensity at radius r is $E_r = q/r^2$.

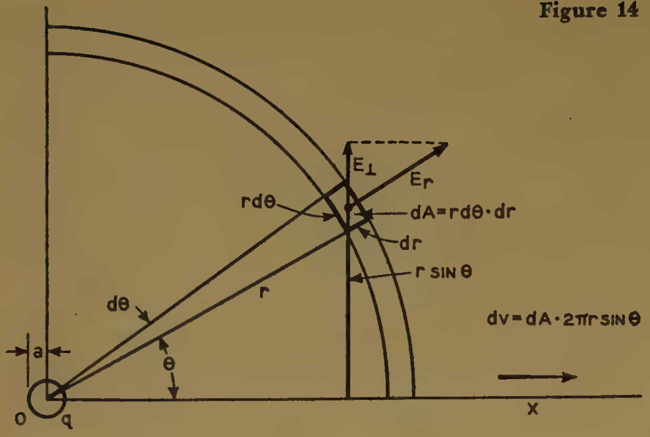
The component of E_r resolved perpendicular to the line of motion OX is

$$E_{\perp} = E_r \sin\theta = \frac{q}{r^2}\sin\theta \tag{50}$$

substituting this value in the expression for dm in the foregoing, we have

$$\begin{aligned} dm &= \frac{\left(\frac{q}{r^2}\sin\theta\right)^2}{8\pi}\,\frac{2}{c^2}\times 2\pi r^2 dr \times \sin\theta d\theta \\ &= \left(\frac{q^2}{8\pi}\times\frac{2}{c^2}\right)2\pi r^{-2}dr\times\sin^3\theta d\theta \end{aligned}$$

Figure 14



$$m=\left(\frac{q^2}{8\pi}\times\frac{2}{c^2}\right)\int_{r\,a}^{\infty}\int_{\theta\,0}2\pi r^{-2}dr\times\sin^3\theta d\theta$$

$$=\frac{q^2}{8\pi}\times\frac{2}{c^2}\left[2\pi\frac{r^{-1}}{-1}\right]_a^{\infty}\times\left[-\cos\theta+\frac{\cos^3\theta}{3}\right]_0^{\pi}$$

$$=\frac{q^2}{8\pi}\times\frac{2}{c^2}\times2\pi\left(\frac{1}{a}\right)\left(\frac{4}{3}\right)$$

$$=\frac{2}{3}\frac{q^2}{a}\frac{1}{c^2}\tag{51}$$

$$m=\frac{2}{3}\frac{e^2}{a}\frac{1}{c^2}\tag{52}$$

This is the formula arrived at by J. J. Thomson for the mass of the electron. The above result confirms the accuracy of the field–mass equation and the validity of the concept attributing mass directly to the electric field itself without recourse to the conventional additional steps which attribute electronic mass to the magnetic field and attribute magnetic field to electric field in motion. The foregoing method is clearly more fundamental since it has been shown that magnetic energy is simply the kinetic energy of the electric field.

Appendix V

In order to fix ideas, it may be helpful to substitute the known values of charge and mass in the accepted formulas for the electron and calculate the numerical values of its mechanical and electrical intensities. These intensities work out to be of tremendous magnitude.

The electron, popularly thought of as a light balloon-like charge of pure negative electricity, turns out to be a physical structure enormously stronger, harder, and heavier than anything we know of as matter in bulk and entirely devoid of the kind of thing we ordinarily think of as electric charge at its center.

It will be understood that at present, the electron radius is merely the limit of integration in J. J. Thomson's formula (equation 52) giving an electron mass equal to the value deduced from experiment. The mass is entirely outside the surface of this limiting sphere and resides entirely in the electric field as shown above. The structure tying these tremendous stresses together is unknown.

Taking the present accepted values of electron charge and mass as

$e=4.77\times10^{-10}$ statcoulomb
$m=9\times10^{-28}$ gram
$c=3\times10^{10}$ centimeters per second

The radius of the electron from Thomson's formula is

$$a=\frac{2}{3}\frac{e^2}{m}\frac{1}{c^2}$$

$$=\frac{2}{3}\times\frac{[4.77\times10^{-10}]^2}{9\times10^{-28}}\times\frac{1}{9\times10^{-20}}$$

$$=1.87\times10^{-13}\text{ centimeter}$$

The potential at the surface of the electron sphere is

$$V=\frac{q}{r}$$

$$=\frac{4.77\times10^{-10}}{1.87\times10^{-13}}$$

$$=2{,}550\text{ statvolts}$$
$$=765{,}000\text{ volts}$$

The electric field intensity or voltage gradient at the electron surface is

$$E=\frac{q}{r^2}$$

$$=\frac{4.77\times10^{-10}}{[1.87\times10^{-13}]^2}$$

$$=1.36\times10^{16}\text{ statvolts per centimeter}$$
$$=4.08\times10^{18}\text{ volts per centimeter}$$

The charge density at electron surface is

$$\sigma=\frac{\text{charge}}{\text{area}}$$

$$=\frac{e}{4\pi r^2}$$

$$=\frac{4.77\times10^{-10}}{4\pi[1.87\times10^{-13}]^2}$$

$$=1.08\times10^{15}\text{ statcoulombs per square centimeter}$$

The force of mechanical tension at electron surface is

$$F=2\pi\sigma^2$$
$$=2\pi[1.08\times10^{15}]^2$$
$$=7.4\times10^{30}\text{ dynes per square centimeter}$$
$$=7.55\times10^{24}\text{ kilograms per square centimeter}$$
$$=7.55\times10^{21}\text{ metric tons per square centimeter}$$

These values naturally direct attention to the nature of the junction which is able to sustain such tremendous forces.

If we contemplate the disruption of this physical junction, it is evident that the electric field system will recede into space at the velocity of light as a spherical wave and disappear as radiation. Thus mass is convertible into radiation by the disruption of the nuclear junction. The question now arises as to what becomes of the electron charge.

The answer to this question readily is given. Clearly the electron charge, as a physical entity, is a thing which never existed. It is a mathematical quantity appearing in our equations at the terminus of tubes of electric flux. It is a measure of and equivalent of electric flux.

Electric flux is the real physical entity, possessing inertia, elasticity, tension, lateral pressure, and all the physically observable effects. Electric charge is the name given to the terminus of the strain system. It corresponds, by analogy, to the terminus, fastening, or hook at the end of a helical spring. We should not, as we commonly do, mistake the hook for the spring. In brief, electric charge appears as a mathematical fiction, useful and convenient in mentally and mathematically following field phenomena.

The Forces Between Moving Charges

R. D. SARD

This straightforward statement of the present generally accepted theory is a correlation of widely scattered material well-known to scholars in the field, but heretofore not collected.

THE QUESTION has been raised[1] as to whether there is any magnetic force between two charges moving in the same direction with the same speed. In fact, one author[2] has given a flat negative answer to the question and proposed a drastic modification of electromagnetic theory.

The answer depends, however, on the relative motion of the observer. An observer riding along with one of the particles would, indeed, find the other particle to be at rest, and his measurements would reveal no force between the particles other than the electrostatic repulsion or attraction given by Coulomb's law. But an observer in the laboratory, for whom both particles are in motion, would conclude from his observations that there is a magnetic force between the particles as well as an electric one. And it is this laboratory reference system that is used in all practical calculations, and in terms of which we normally think.

The forces between two charged particles of equal velocity were calculated long ago by Heaviside[3] who remarked, ". . . it is very exceptional to arrive at simple results, and these now in question are sufficiently free from complexity to take a place in textbooks of electricity." A detailed treatment of the field due to a moving charge and the force acting on a moving charge can be found in any textbook covering electron theory.[4] The field is obtained as a solution of Maxwell's equations. Figure 1 indicates the result. For a charge moving with constant velocity, the electric field is radial, like the static one, but differs in that the straight lines of force are crowded toward the plane perpendicular to the direction of motion. The magnetic field is circular, the lines of force being circles perpendicular to the line of motion and centered on it. The equations are

$$\left.\begin{aligned} E_x&=-(1-\beta_1^2)\frac{e_1}{s_1^3}x_1 & H_x&=0\\ E_y&=-(1-\beta_1^2)\frac{e_1}{s_1^3}y_1 & H_y&=\beta_1(1-\beta_1^2)\frac{e_1}{s_1^3}z_1\\ E_z&=-(1-\beta_1^2)\frac{e_1}{s_1^3}z_1 & H_z&=-\beta_1(1-\beta_1^2)\frac{e_1}{s_1^3}y_1 \end{aligned}\right\}\quad(1)$$

with

$$\beta_1=v_1/c$$

and

$$s_1=\sqrt{x_1^2+(1-\beta_1^2)(y_1^2+z_1^2)}$$

These equations give the field at the origin due to a particle of charge e_1, located at the point $(x_1,\ y_1,\ z_1)$ and moving with the velocity v_1 in the x direction. The charge and electric field are in electrostatic units, the magnetic field in electromagnetic units, distance in centimeters, and time in seconds. c is the speed of light.

The force on a particle of charge e_2 moving with the velocity $(v_{x_2},\ v_{y_2},\ v_{z_2})$ in an electric field $(E_x,\ E_y,\ E_z)$ and a magnetic field $(H_x,\ H_y,\ H_z)$ is given by the general expression due to Lorentz:

$$\left.\begin{aligned} F_{x_2}&=e_2E_x+\frac{e_2}{c}(v_{y_2}H_z-v_{z_2}H_y)\\ F_{y_2}&=e_2E_y+\frac{e_2}{c}(v_{z_2}H_x-v_{x_2}H_z)\\ F_{z_2}&=eE_{z_2}+\frac{e_2}{c}(v_{x_2}H_y-v_{y_2}H_x) \end{aligned}\right\}\quad(2)$$

This force is the vector sum of a push in the direction of the electric field and a side-thrust perpendicular to both the magnetic field and the velocity. Thus a particle of charge e_2 at rest at the origin is acted on by the force

$$\left.\begin{aligned} F_{x_2}&=-e_2e_1(1-\beta_1^2)\frac{x_1}{s_1^3}\\ F_{y_2}&=-e_2e_1(1-\beta_1^2)\frac{y_1}{s_1^3}\\ F_{z_2}&=-e_2e_1(1-\beta_1^2)\frac{z_1}{s_1^3} \end{aligned}\right\}\quad(3)$$

due to the particle of charge e_1 moving with velocity $v_1=\beta_1c$ in the x direction. This is simply the push due to the flattened electric field of the moving charge. If particle 2 is in motion, a side-thrust is added; if it has velocity $v_2=\beta_2c$ in the x direction, the force on it is (see Figure 2)

$$\left.\begin{aligned} F_{x_2}&=-e_2e_1(1-\beta_1^2)\frac{x_1}{s_1^3}\\ F_{y_2}&=-e_2e_1(1-\beta_1^2)\frac{y_1}{s_1^3}+\beta_2\beta_1e_2e_1(1-\beta_1^2)\frac{y_1}{s_1^3}\\ &=-e_2e_1(1-\beta_1^2)\frac{y_1}{s_1^3}(1-\beta_2\beta_1)\\ F_{z_2}&=-e_2e_1(1-\beta_1^2)\frac{z_1}{s_1^3}+\beta_2\beta_1e_2e_1(1-\beta_1^2)\frac{z_1}{s_1^3}\\ &=-e_2e_1(1-\beta_1^2)\frac{z_1}{s_1^3}(1-\beta_2\beta_1) \end{aligned}\right\}\quad(3a)$$

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The longitudinal component of the force on particle 2 is not affected by its motion, but the transverse components are reduced by the factor $(1-\beta_2\beta_1)$. This reduction is due to the magnetic attraction. As the speeds approach that of light ($\beta_1 \rightarrow 1$, $\beta_2 \rightarrow 1$), the magnetic attraction approaches the electric repulsion in magnitude. All components of the force approach zero, but the transverse components do so more rapidly.

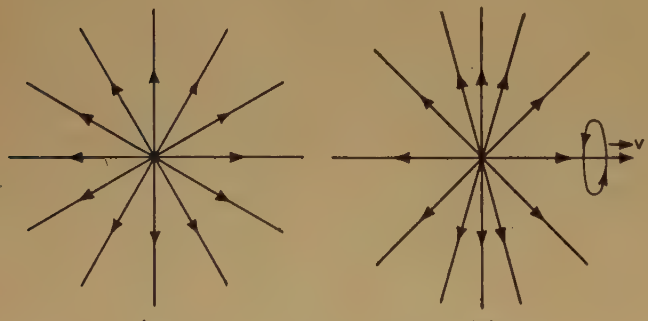
To determine the motion of particle 2, one equates the force acting on it to its rate of change of momentum:

$$\left.\begin{aligned}F_{x2}&=\frac{d}{dt}\left(\frac{m_{0_2}}{\sqrt{1-\beta_2^2}}v_{x2}\right)\\&=\frac{m_{0_2}}{(1-\beta_2^2)^{3/2}}\frac{dv_x}{dt}\\F_{y2}&=\frac{d}{dt}\left(\frac{m_{0_2}}{\sqrt{1-\beta_2^2}}v_{y2}\right)\\&=\frac{m_{0_2}}{\sqrt{1-\beta_2^2}}\frac{dv_{y2}}{dt}\\F_{z2}&=\frac{d}{dt}\left(\frac{m_{0_2}}{\sqrt{1-\beta_2^2}}v_{z2}\right)\\&=\frac{m_{0_2}}{\sqrt{1-\beta_2^2}}\frac{dv_{z2}}{dt}\end{aligned}\right\} \qquad (4)$$

Here m_{0_2} is the rest-mass of particle 2. These expressions take account of the increase of inertia with velocity.

The procedure to determine the motion of a charged particle is, then

1. By means of Maxwell's field equations, determine the electromagnetic field at the particle due to the motions of the other particles.
2. Determine the force acting on the particle, by means of the Lorentz expression, equation 2.
3. Equate this force to the rate of change of momentum, equation 4.



(A) (B)

Figure 1. Electric lines of force of a positive point charge

In A, the charge is at rest, and the lines are distributed equally in all directions. There is no magnetic field. In B the charge is moving with the velocity v to the right. The lines of force are crowded toward the plane perpendicular to the direction of motion; this crowding only becomes appreciable when v is of the same order of magnitude as c, the speed of light. Because of the motion, there is also a magnetic field. The magnetic lines are circles perpendicular to the line of motion and centered on it; one of them is sketched in

It hardly need be remarked that Maxwell's equations, the Lorentz force equation, and equation 4 for the rate of change of momentum have been verified quantitatively for large and small speeds by numerous experiments and practical applications. Note that in the procedure given, all calculations are made from the point of view of the laboratory reference system.

Since the magnetic force is a side-thrust, the forces between two moving particles (though equal and opposite) are not directed along the line joining them (see Figure 2). This is evident in equation 3*a*, where the magnetic force reduces the transverse components without affecting the longitudinal one. Except when the two particles are in line ($y_1=z_1=0$) or abreast ($x_1=0$), the forces tend to line them up in the direction of motion. This leads to the conclusion that a conducting sphere in motion would not have a uniform distribution of charge on its surface; the charge would tend to pile up at the front and back.

If this were the case, we should be able to detect absolute motion: only on a sphere at rest with respect to the ether would there be a uniform distribution of charge. Many experiments, such as that of Michelson and Morley, have shown, however, that it is impossible to detect absolute motion, so that our conclusion is in the nature of a paradox. The paradox is resolved by the hypothesis of Lorentz and Fitzgerald, according to which, bodies in motion are flattened in the direction of the motion, the shortening being given by the factor $\sqrt{1-\beta^2}$. The transverse dimensions are unchanged. The sphere then becomes oblate, the flattening being just enough to counteract the tendency of the charge to pile up at the poles. If one also postulates (after Lorentz) that clocks in the moving system run slower, by the same factor $\sqrt{1-\beta^2}$, one is able to use Maxwell's equations, the Lorentz force law, and the equation 4 for the increase of mass with velocity, consistently in all cases without obtaining any result that would make it possible to detect absolute motion.

Absolute motion being undetectable, one reference system is as good as another, and we seem to be back at the difficulty with which we started: how to explain the fact that an observer riding along with the electrons would detect no magnetic force? The Lorentz-Fitzgerald contraction, the slowing down of clocks, and the increase of mass with velocity, give the answer. Thus, consider two electrons moving line abreast, a distance d apart, down an evacuated tube of length l (Figure 3). Observing them in the laboratory, we note that they spread apart a distance $2\Delta y$ in going the length l. According to equations 3*a* and 5, Δy is given by the solution of

$$\frac{d^2y}{dt^2}=\frac{e^2}{m_0}(1-\beta^2)\frac{1}{y^2} \qquad (5)$$

(we have taken the $x-y$ plane in the plane of the lines of motion, so that $z=0$ as well as $x=0$). Considering the case of fast electrons that are not too close together, we can set $y=d$ in this differential equation, and then we obtain, analogous to $s=1/2(gt^2)$:

$$\Delta y=\frac{1}{2}\frac{e^2}{m_0c^2}\frac{l^2}{d^2}\left(\frac{1-\beta^2}{\beta^2}\right) \tag{5a}$$

The spreading approaches zero as the speed of the electrons approaches that of light. Let us now solve the problem in a reference system moving with the electrons. Quantities measured in this system are indicated by primes. Both electrons are essentially at rest, and the transverse force is simply e^2/y'^2. The mass is the rest-mass. Therefore,

$$\frac{d^2y'}{dt'^2}=\frac{e^2}{m_0}\frac{1}{y'^2} \tag{6}$$

Making the same assumption that $\Delta y'$ is small compared to d', as before,

$$\Delta y'=\frac{1}{2}\frac{e^2}{m_0}\frac{t'^2}{d'^2} \tag{6a}$$

t' is the time interval measured in the moving system corresponding to passage from one end of the tube to the other. Because clocks run slower in the moving system

$$t'=\sqrt{1-\beta^2}\,t$$

$$=\sqrt{1-\beta^2}\left(\frac{l}{\beta c}\right)$$

and

$$\Delta y'=\frac{1}{2}\frac{e^2}{m_0c^2}\frac{l^2}{d'^2}\left(\frac{1-\beta^2}{\beta^2}\right) \tag{6b}$$

The Lorentz-Fitzgerald contraction does not affect transverse dimensions, so $d'=d$ and $\Delta y'=\Delta y$. Equation 6*b* agrees with equation 5*a*. The observer in the moving system sees two electrons that are initially at rest get spread apart the distance $2\Delta y$; the observer in the laboratory sees two electrons moving with velocity $v=\beta c$ get spread apart the same distance $2\Delta y$. The absence of the magnetic force in the moving reference system (as well as the lower value of the mass, which is merely the rest-mass) is made up for by the slowing down of clocks. In this way, the paradox is resolved.

The Lorentz-Fitzgerald contraction does not enter into this example, because all the distances involved are transverse to the motion. When the electrons are not moving line abreast, it is necessary to invoke the contraction as well as the slowing down of clocks. This can be seen very easily in the case where the two electrons are in line.

We see that in order to reconcile Maxwell's equations, which are in agreement with experiment, with the negative results of all the experiments designed to reveal absolute motion, it is necessary to admit the Lorentz-Fitzgerald contraction and the slowing down of clocks. Einstein,[5] in his "Special Theory of Relativity," derived these from a careful analysis of the notion of simultaneity and from two postulates.

1. That of equivalence of any two reference systems in uniform motion with respect to one another (the principle of relativity).
2. That of the equality of the speed of light in all such systems.

He also derived from these assumptions the formulas for the transformation of mechanical and electromagnetic quantities from one such reference system to another. This made it possible to solve dynamical problems by solving the corresponding static ones, and then transforming the results to the laboratory reference system. Our basic equations 1–4 easily can be derived in this way. Note that these include the Lorentz law of force, equation 2, and the expression for the increase of mass with speed, equation 4. Without the theory of relativity, these would appear as additional assumptions required by experiment. Einstein's theory can be regarded as a drastic modification of our fundamental notions of the measurement of length and time to fit them to the facts of electricity and magnetism.

Let us now apply our general results to the type of situation arising in practice, where large numbers of charged particles are involved. Suppose that particle 1 is one of a stream B of electrons, the number per centi-

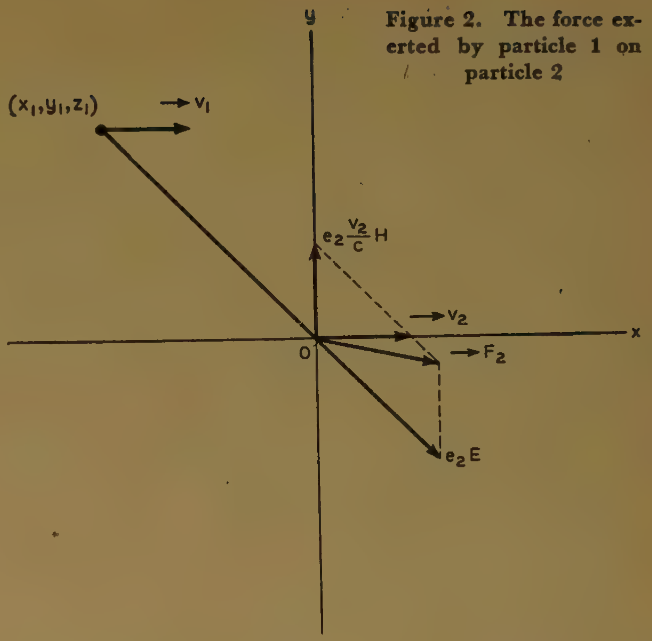


Figure 2. The force exerted by particle 1 on particle 2

Particle 1 is moving through the point (x_1, y_1, z_1) *with velocity* v_1 *in the x direction. Particle 2 is moving through the origin O with velocity* v_2 *in the x direction. E and H are respectively the magnitudes of the electric and magnetic fields at O due to particle 1; they are given by equation 1. The force on particle 2 is the vector sum of the push,* e_2E, *due to the electric field, and the side-thrust,* $e_2(v_2/c)H$ *due to the magnetic field. It has a component perpendicular to the line joining the two particles, tending to move particle 2 up into line with particle 1* meter length being σ_B. Integration of equation 1 over the whole stream gives for the field at the origin, which is a distance d below the stream,

$$\left.\begin{array}{ll} E_x=0 & H_x=0 \\ E_y=\dfrac{2e\sigma_B}{d} & H_y=0 \\ E_z=0 & H_z=\dfrac{2\beta_B e\sigma_B}{d} \end{array}\right\} \qquad (7)$$

(The $x-y$ plane is that of the stream and the origin.) Note that the relativistic factor, $(1-\beta_B{}^2)$, has cancelled out in the integration, leaving us the familiar formulas for the electric and magnetic fields of a linear distribution of charge and current. These hold, then, for any velocity of the charged particles. From equations 7 and 2, the force on an electron at the origin, moving with the velocity v_A in the x direction, is

$$\begin{aligned} F_{x_A}&=0 \\ F_{y_A}&=-\frac{2e^2\sigma_B}{d}(1-\beta_A\beta_B) \qquad (8) \\ F_{z_A}&=0 \end{aligned}$$

From this expression, we can calculate the force between two parallel wires carrying current. Each wire consists of a number of positive ions, ρ per centimeter, of charge Ze, and a number of mobile electrons, σ per centimeter, moving along the wire. The force on wire A exerted by wire B is the sum of four terms: the force on the electrons of A exerted by the electrons of B, the force on the electrons of A exerted by the positive ions of B, the force on the positive ions of A exerted by the electrons of B, and the force on the positive ions of A exerted by the positive ions of B. Applying equation 8 to obtain each of the four terms and adding, we get

$$\begin{aligned} F_{x_A}&=0 \\ F_{y_A}&=\frac{2}{d}\frac{I_AI_B}{c^2}-\frac{2e^2}{d^2}(\sigma_B-z_B\rho_B)(\sigma_A-z_A\rho_A) \qquad (9) \\ F_{z_A}&=0 \end{aligned}$$

The second term in F_{y_A} is simply a possible electrostatic repulsion or attraction, vanishing when either of the wires is electrically neutral. We then are left with the familiar expression for the force between two parallel wires carrying current, an attraction when the currents are in the same sense, a repulsion when they are opposite.

The relativistic laws that we have been discussing only can become appreciably different from the familiar unrelativistic ones when speeds approaching that of light are involved. Such speeds are obtained in the electron accelerators now being applied in nuclear physics (these accelerators already have found a practical use in another field, the X-ray examination of thick metal plates, where the X rays are produced by the stopping of the high-energy electrons). It may be appropriate, therefore, to conclude with some remarks about the spreading of a high-speed electron beam due to mutual repulsion of the similarly charged electrons (space-charge defocusing). Equation 8 gives the force exerted on an electron of the beam by one of the filaments composing it. Hence, the repulsive force on an electron at a distance y from the axis of the beam is

$$F_y=2e^2\sigma(1-\beta^2)\omega \qquad (10)$$

where σ is now the total number of electrons per centimeter length of beam and ω is some function of the distribution of electrons over the cross section of the beam and of the displacement y from the axis, of the electron considered. The equation of motion of the electron is

$$\frac{m_0}{\sqrt{1-\beta^2}}\frac{d^2y}{dt^2}=2e^2\sigma(1-\beta^2)\omega \qquad (10a)$$

It is clear that the spreading of the beam is reduced not only by the increase of mass with velocity, but also by the reduction of the repulsive force. This decrease in the repulsive force is due (from the point of view of the laboratory reference system) to the increase

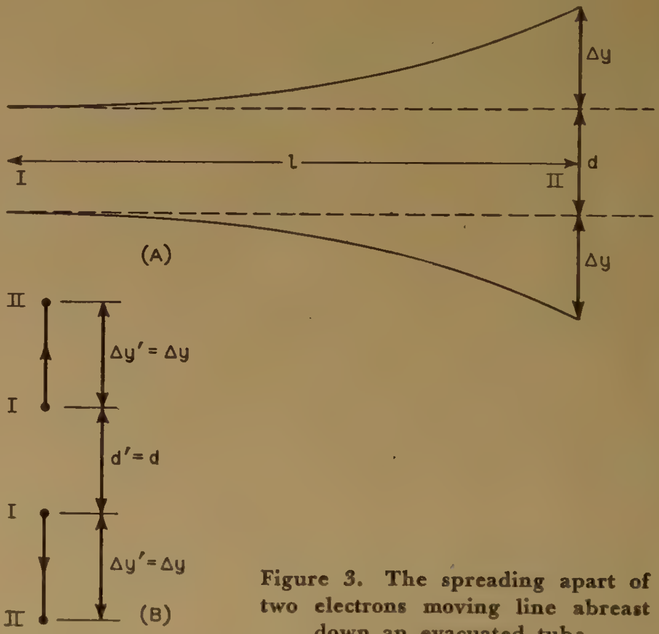


Figure 3. The spreading apart of two electrons moving line abreast down an evacuated tube

Δy, which is small compared to d, is exaggerated in the drawing. In A the situation is depicted from the point of view of an observer at rest with respect to the tube. At the start, I, which might be the exit from an electron gun, the two electrons are a distance d apart. At II, which might be a fluorescent screen, they have spread apart an additional distance $2\Delta y$. The force producing this spreading is the repulsive electric force diminished by the attractive magnetic one. The time elapsed is approximately $l/v=l/\beta c$. In B, the situation is shown from the point of view of an observer moving down the tube with a velocity equal to that of the electrons. Initially I, the electrons are at rest, a distance d apart. Finally, II, they have spread apart the additional distance $2\Delta y$. The force producing this spreading is the electrostatic repulsion, which is $(1/1-\beta^2)$ times the net repulsion in reference system A. The mass is $(1-\beta^2)$ times the mass in reference system A. The time elapsed is $(1-\beta^2)$ times that in reference system A. The increased force and the decreased mass are made up for by the decreased time elapsed; and the same physical result, the spreading $2\Delta y$, is obtained whichever point of view one takes

of the magnetic attraction, which approaches the electric repulsion in absolute value as β approaches 1. An observer moving with the electron would observe no magnetic attraction, of course, but the contraction of his measuring rods and the slowing down of his clocks would compensate for this, making his observations consistent with those made in the laboratory reference system. In the case of the betatron, for example, the number of electrons in the orbit is constant, and its size in the laboratory system is constant. As Kerst[6] has pointed out, the length of the orbit in the moving reference system increases as the observer's measuring rod shrinks, and hence, the number of electrons per centimeter of beam decreases. Therefore, the repulsion, which is now purely electrostatic, approaches zero also in this reference system. In fact with

$$t' = \sqrt{1-\beta^2}\,t$$

and

$$\sigma' = \sqrt{1-\beta^2}\,\sigma$$

equation 10*a* becomes

$$m_0 \frac{d^2y'}{dt'^2} = 2e^2\sigma'\omega' \qquad (10b)$$

which is just the equation of motion one would write for the situation as seen in the moving system ($\omega=\omega'$, since it involves only transverse distances).

It follows from equation 10*a* that once the electrons have been brought to a speed near that of light, there will be little trouble from then on due to space-charge defocusing. This may be of importance in the functioning of the betatron, where each electron travels a huge distance in the doughnut shaped tube before striking the target. In the case of the 100-million-volt machine at the General Electric Research Laboratory,[7] the distance is about 260 miles (250,000 revolutions in an orbit of 66-inch diameter); while the rest-mass of the electron is so small (corresponding to 0.51 million electron volts), that a speed 0.9 that of light is already achieved with a kinetic energy of only 0.66 million volts. In the betatron, as in the other electron accelerators currently being discussed, there are focusing forces which hold the beam together. The conclusion to be drawn from equations 10, 10*a*, and 10*b* is that these focusing forces do not need to be as large as one would think if one neglected the magnetic attraction between the electrons in the beam.

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Engineering—Science, Industry, or Labor?

In the past there have been few ties between the engineers and the other professions, but for that matter, the engineers have not exhibited much coherence among themselves. Industry has used their services freely but logically has felt little responsibility in guarding their special interests. The engineers, on their part, have drawn heavily upon the several fields of science without feeling any strong impulse to act jointly with scientists in the development of general scientific interests. They are, in consequence of this peculiar relationship, literally and figuratively "in the middle."

Regardless of the numerical strength and the technological power any group may possess, splendid isolation is commonly an element of weakness, as the engineers already have discovered. More than 25 years ago, state governments opened a drive on the licensing of engineers, making a license compulsory for anyone practising within the confines of the individual states. In theory the procedure was reasonable, for it was prompted as a measure of protection against incompetence, but in practice licensing has had many inconvenient and even vicious aspects which have been remedied only in part. At times and in certain states local talent has been favored regardless of competence, and in such cases the public has received less protection rather than more. Few engineers have deep geographic roots, and to carry on a normal consulting practice they must be licensed in several states and must familiarize themselves with the legal requirements of all states in which they ply their specialty. Yet, when

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Essential substance of an article written by Howard A. Meyerhoff, a member of the American Institute of Mining and Metallurgical Engineers, and published in the *Bulletin* of the American Association for the Advancement of Science, Washington, D. C., volume 5, number 9, September 1946, page 69.

these questions first arose, their implications were but dimly appreciated; united action was lacking; and a heterogeneous and inequitable procedure was foisted upon the profession.

CONTACT WITH UNIONS

Within the past six or seven years the question of unionization of engineers in industry has arisen, and once again the profession is confused and disunited and—too often—uninformed and uninterested. Engineers come into contact with labor unions in two distinct ways:

1. Practically every engineering project of any size calls for contracts with unionized crafts, and the planning, specifications, and contracting must be adapted to the labor situations which exist locally.

2. Engineers not infrequently find early employment in shops and drafting rooms in which other employees are unionized. Under open shop contracts they have the option of joining the union, and under closed shop contracts they are compelled to join.

It is with the second of these situations that the American Society of Civil Engineers has become concerned, and has testified before the Labor Committee of the House of Representatives:

> "The fundamental difficulty with the present labor law as it affects professional employees is that it places professional employees and nonprofessional employees within one incompatible category. Their viewpoints and attitudes are inherently different. The abilities and work characteristic of professional men are not susceptible of standardization in accordance with nonprofessional criteria.
>
> ". . . three specific points are of fundamental importance for inclusion in any legislation which establishes standards for collective bargaining between employees and employer, namely:
>
> "1. Any group of professional employees, having a community of interest and who wish to bargain collectively, should be guaranteed the right to form and administer their own bargaining unit and be permitted free choice of their representatives to negotiate with their employer.
>
> "2. No professional employee, or group of employees, desiring to undertake collective bargaining with an employer, should be forced to affiliate with, or become members of, any bargaining group which includes nonprofessional employees, or to submit to representation by such a group or its designated agents.
>
> "3. No professional employee should be forced against his desires to join any labor organization as a condition of his employment or to sacrifice his right to individual, personal relations with his employer in matters of employment conditions.
>
> "Legislation which would cover these three points, and cover them without possibility of contrary interpretation, would satisfy one of the avowed purposes of the present National Labor Relations Act."

RELATION TO SCIENTIST

Engineers and scientists have comparable training and comparable standards of precision and ethics, and they both make a living by means of their professions. The academic scientist may tend to view unionization with more detachment and idealism than his more "practical" colleagues in engineering and other industrial occupations, but by and large neither group has distinguished itself by its knowledge and scientific approach to organization within industry and in the teaching professions.

Organization has always had a practical objective—namely, the protection of workers' interests, which are usually defined as wages, hours, and working conditions. Where there is no need for protection, unions rarely thrive, though they may exist. During the depression professional men found themselves hired as draftsmen or mechanics and were treated like their co-workers who lacked degrees. During the war engineers in supervisory positions soon were outnumbered by men with no formal training and were treated in the same way.

Thus the need arose from the protection of the interests of professional men not only with employers but also with the unions whose chief concern is with the nonprofessional worker. The problem is with us and it will stay; therefore it must be met and solved with intelligence and insight. Professional men have too large a financial investment in their education and experience to ignore protection of interests for themselves or for those of their colleagues who may need it.

The need for fuller co-operation among professional men in the fields of science and engineering is as pressing elsewhere as it is in the matter of unionization. The engineers foresaw the shortage of personnel in industry and in the classroom, and precipitated the effort to have selective service appropriately relaxed. But the academic scientists, though distraught in departments which were understaffed, overenrolled, and overworked, took little part in the effort, either individually or collectively through their societies. The engineers, on the other hand, have assumed too little responsibility in informing their scientific colleagues regarding the scientific aims, achievements, and requirements of the engineers.

NECESSITY FOR CO-OPERATION

The times demand co-operative effort, and it takes two to co-operate. The current problem of unionization has shown the engineers, that, as a group, they are not industrialists by virtue of being engineers, or they would not need to protect their interests in certain industrial situations. They are not laborers, for their special and expensive mental equipment makes the usual labor contract inapplicable to their peculiar problems in industry. They are, in fact, professional scientists whose creative skill ranges over many fields in the application of scientific discovery, and it behooves them and the academic scientists to work jointly on the solutions of such common problems as licensing, personnel, unionization, United Nations Education Scientific and Cultural Organization, and even such mundane affairs as joint sessions.

Electric Power in China

FRED O. McMILLAN
FELLOW AIEE

The handicap under which China has attemped to start industrialization is due largely to the inadequacy of her electric power installations. Installed generating capacity per capita in China is 1.7 watts, less than 0.5 per cent of that in the United States. Future power development has been planned by the Chinese National Resources Commission involving almost two million kilowatts to be installed in the next five years. This ambitious program, which almost will quadruple the present capacity, may meet with success or failure depending upon the outcome of the present civil war and the establishment of economic stability.

ELECTRIC POWER development in China has been slow because she has been essentially an agrarian and not an industrial nation. It is estimated that 85 per cent of the people live by tilling the soil. The economic status of the average Chinese citizen has been very low and this combined with an inherent reluctance to discard established methods of obtaining light and power has retarded the general use of electricity for these services, especially in the interior.

The kilowatts of installed electric power generating capacity of record in China in 1944, together with the population by provinces and the installed generating capacity in watts per capita, are shown in Table I. Manchuria and Formosa are excluded from the tabulation because of Japanese control, until the end of World War II. An examination of the table shows that there are four provinces, comprising Inner and Outer Mongolia with a total population of six million, that have no electric power plants. The other provinces have installed capacities ranging from 100 kw in Tibet to 321,000 kw in Kiangsu. Further analysis of the data shows that industry, transportation, and contact with the western countries have been important factors in determining the extent to which electric energy has been used. This is shown by the fact that the six coastal provinces, which contain 41 per cent of the population, have 89 per cent of the installed generating capacity. Eight of the important cities in these provinces have 74 per cent of the generating capacity while Shanghai alone has 37 per cent of the total capacity.

A large part of the generating capacity in China is driven by steam turbines supplied from coal fired boilers and a few Diesel prime movers. Hydroelectric plants represent less than one per cent of the total capacity. The very small amount of hydroelectric power development probably is due largely to two conditions: first, the large cities and the prewar industrial developments are for the most part on the coast and relatively flat coastal plains remote from good hydroelectric power sites and second, hydroelectric plant costs are high, especially for the small developments, because many of the small streams are subject to very large annual fluctuations in flow and during flood stages carry large quantities of silt.

China does not have facilities for manufacturing steam turbogenerator sets, therefore this equipment has been imported. Over a period of approximately 20 years preceding closure of her ports by Japan in World War II, she purchased, in addition to smaller units, 39 turbogenerators ranging in capacity from 5,000 to 22,500 kw with an aggregate capacity of 440,000 kw or 64 per cent of the total installed capacity. These units were purchased in seven countries. The per cent of the kilowatt capacity supplied by each is as follows: France 2.9, Czechoslovakia 4.5, Switzerland 4.8, Japan 7.8, United States 15, Germany 31, and Great Britain 34 per cent.

On a kilowatt basis the ownership of the generating capacity in China is approximately 53 per cent private, 7 per cent government, and 40 per cent foreign.

In April 1935 the National Resources Commission of China was organized by the government to carry out the following functions:

(*a*). To develop and control the basic industries.

(*b*). To develop and control the important mining enterprises.

(*c*). To develop and control the power enterprises.

(*d*). To exercise administration over other enterprises as may be designated by the Government.

The guiding principles under which the Commission was operating in 1944, to carry out the foregoing functions, were given by Vice-Chairman Chien, Chang-Chao.

Essential substance of an article written especially for *Electrical Engineering* embracing material originally presented before the AIEE San Francisco Section.

Fred O. McMillan was sent to China by the United States State Department in 1943 and 1944 as a specialist in electric engineering at the request of the Chinese government. Data on the electric power developments are based largely upon observations made and information collected on that mission. Work was done for the ministries of economic affairs, education, and communications. Professor McMillan is now back at Oregon State College, Corvallis, Oreg., as head of the department of electrical engineering.

Acknowledgment is made of the services of Doctor Wong, Wen-hao, vice-president of the executive yuan and minister of economic affairs, Mr. Chen, Li-fu, minister of organization of the Kuomintang Party and formerly minister of education, Mr. Tseng, Yang-fu, minister of communications, and Mr. Chien, Chang-chao, chairman of the National Resources Commission.

Mr. Chien recently was made chairman succeeding Doctor Wong, Wen-hao, who was advanced to the vice-presidency of the executive yuan. The guiding principles as given by Mr. Chien are as follows: "In all its endeavors to carry out these functions (objectives *a* through *d*) efficiently the Commission is guided by the following fundamental principles:

1. "To make China a modern state and to improve her economic conditions, it is necessary that her industrialization be brought about as quickly as possible.

2. "To accelerate the industrialization of China it is necessary to develop heavy industries as a prerequisite.

3. "To prevent anti-social or monopolistic tendencies in the development of heavy industries, it is necessary that the work be placed in the hands of the Government.

"The reasons for the afore-mentioned principles are obvious and are based on economic political and social considerations in China."

Recently there have been indications that if industrial development is retarded by the inability of the government to make sufficiently rapid progress toward industrialization, private enterprise will be permitted to participate in the development of heavy industries.

Before World War II there were very few power plants in the interior of China and they were of low capacity. In the eight hinterland provinces of Hunan, Kansu, Kwangsi, Kweichow, Shensi, Sikang, Szechwan, and Yunnan, which have a population of 127 million, the total generating capacity was approximately 20,000 kw. Table II shows that four cities in three of these provinces had 19,930 kw generating capacity and this was essentially all of the capacity serving this large population in an area of 923,000 square miles.

In 1938 the National Resources Commission began building additional power plants in the interior to serve the essential war industries and activities. These plants were equipped with such new machinery as could be obtained, but for the most part they were equipped with machinery moved back from Japanese occupied territory and that manufactured by the newly established factories in the interior. The commission also co-operated with five provinces in constructing six different plants with a total capacity of 3,900 kw. The geographical distribution and capacity of the power plants constructed in Free China during World War II are shown in Table III.

A unique plant, which was designed to meet security requirements under war conditions, is the Pen Shui Tung plant near Yanglin, Yunnan Province. This is a mine mouth plant built in a bombproof cave excavated from a limestone mountain. It has a protective overburden of solid rock 42 meters (138 feet) thick. The stack is excavated through the rock overburden and protected at the top with a reinforced concrete cone to deflect any bomb directed toward the stack opening. The turbogenerator is a Siemens-Schuckert 2,000-kw machine. Coal is obtained from a mine approximately 100 meters up stream from the power plant and is discharged directly from dump cars into the hopper of the chain grate stoker. Condensing water is obtained from a diversion dam a short distance above the plant and flows by gravity through the condenser. The condenser cooling water is discharged into an ash sluice which carries all ash from the pit and discharges it into the stream below the plant, where it is carried away without handling. A general view of the Pen Shui Tung plant is shown in Figure 1. In the center background the diversion dam for the condensing water may be seen, smoke from the stack is issuing from the hillside on the right and the round stone structure in the foreground is a fortification for the military guard. This generating plant was completed and put in operation during the summer of 1943. Power is transmitted approximately 76 kilometers (47 miles) at 22,000 volts to Kunming where this plant in conjunction with the Kunming Lake plant serves much of the industry in the area.

In terms of kilowatts the generating capacity added to Free China during the war certainly is not impressive, however, the obstacles that were overcome are very impressive. The available generating capacity was more than doubled in a primitive area, practically without transportation save wooden boats and the backs of men, and essentially without manufacturing facilities, except those salvaged from the war wreckage of the coastal area. All work, both manufacturing and construction, was carried on under frequent bombings and the constant threat of bombing which is very demoralizing.

Table I. Population and Installed Generating Capacity in China in 1944

Manchuria and Formosa Excluded

Province	Population	Kilowatts Installed	Watts Per Capita
Anhwei	22,704,000	3,000	0.13
Chahar	2,305,000	0	0.0
Chekiang	21,776,000	23,000	1.06
Chinghai	1,512,000	200	0.13
Fukien	11,990,000	9,300	0.78
Honan	31,805,000	500	0.02
Hopei	28,644,000	130,000	4.54
Hunan	27,186,000	4,000	0.15
Hupeh	24,658,000	10,000	0.40
Kansu	6,255,000	700	0.11
Kiangsi	13,794,000	6,000	0.43
Kiangsu	36,469,000	321,000	8.80
Kwangsi	14,254,000	4,000	0.28
Kwangtung	32,338,000	78,500	2.43
Kweichow	10,487,000	500	0.05
Mongolia	880,000	0	0.0
Ningsia	735,000	0	0.0
Shansi	11,601,000	8,000	0.69
Shantung	38,099,000	50,700	1.33
Shensi	9,799,000	2,200	0.22
Sikang	1,755,000	600	0.34
Sinkiang	4,360,000	200	0.05
Suiyuan	2,083,000	0	0.0
Szechwan	46,403,000	30,100	0.65
Tibet	750,000	100	0.13
Yunnan	10,853,000	7,800	0.72
All provinces	413,495,000	690,400	1.7

Figure 1. Pen Shui Tung steam power plant near Yanglin, Yunnan Province

At the height of their invasion the Japanese had control of 94 per cent of the electric power generating capacity, leaving only 40,000 kw in Free China with which to carry on the war effort.

Chungking had a wartime population of approximately one million and only 11,000 kw of generating capacity. Fortunately this capacity was not destroyed during the frequent bombings even though the power plant, which housed two 4,500-kw turbogenerators, was damaged badly. Later one of the turbogenerators with its boilers was installed in a cave, excavated from solid rock, to insure the preservation of at least a part of the city's power supply. Chungking was zoned and the zones were supplied power on a schedule different nights of the week to reduce the peak lighting load. In addition to zoning, the voltage on the generators was reduced during the peak lighting load to keep it within the capacity of the generators.

The installed generating capacity per capita in China is 1.7 watts, India 1.9, Russia 36, Japan 71, Italy 99, Germany 105, Great Britain 174, France 195, Sweden 204, Norway 209, Switzerland 338, United States 354, and Canada 461. Some of these values necessarily are based upon prewar data but they serve to show the relative electric power development in various countries.

FUEL FOR POWER GENERATION

China has the fourth largest coal reserve in the world which, according to the 1936 estimates by the National Geological Survey of China, amounts to 231 billion tons, exclusive of Manchuria. This is approximately 25 per cent of the Canadian, 17 per cent of the Russian, and 7 per cent of the United States reserves.

Coal reserves are present to some extent in most of the provinces, as shown in Table IV, but the major reserves are concentrated in the two adjacent provinces Shansi and Shensi. These two provinces have 86 per cent of the known coal reserves and Shansi alone has 55 per cent.

Coal production has developed where utilization and transportation have dictated rather than available reserves. This condition is indicated by Table IV because there is little or no correlation between annual production and the estimated reserves.

Because of the high production of coal in Manchuria, where there are single mines such as the Fushun open-cut mine with an annual output of ten million metric tons, the opinion has become prevalent that the coal reserves of Manchuria are large in comparison with those in other parts of China. This is not the case. The estimated coal reserves in the four provinces of Manchuria are shown in Table V. The total reserves in Manchuria are 4,610 million metric tons or slightly less than 2 per cent of the reserves in the rest of China and approximately 3.6 per cent of the reserves in Shansi Province.

The annual use of coal in China has been about 129 pounds per capita and the reserve is approximately 1.23 million pounds per capita. At the present rate of consumption the reserve would last several centuries, however, if she becomes an industrial nation the per capita coal consumption must increase sharply. The per capita use of coal in the United States is approximately 9,000 pounds or 70 times the use in China.

Coal has been the principal source of energy for the generation of electric power in China and probably will continue to be for many years. There is much similarity between China and the United States in the relative geographical distribution of population, coal reserves, and potential hydroelectric power. The population density is high in the east and central portions with sparse population in the west. The coal reserves are highly concentrated in Shansi and Shensi provinces, which have a similar geographical location in China to that of Pennsylvania in the United States. The potential hydroelectric power sites are largely in the central interior, the west, and the southwest, which has considerable similarity to the hydroelectric power distribution in the United States. Therefore, it appears reasonable to speculate that when the power development in China has reached considerable magnitude the distribution between fuel and hydroelectric plant capacity and energy generation may be proportioned

Table II. Major Prewar Power Installations in the Interior of China

Province	City	Power Company	Kilowatts Capacity
Hunan	Changsha	Hunan Electric Light Company	2,000
Szechwan	Chengtu	Chining Electricity Company	3,000
	Chungking	Chungking Power Company	11,000
Yunnan	Kunming	Yaolung Power Company	3,930
Total			19,930

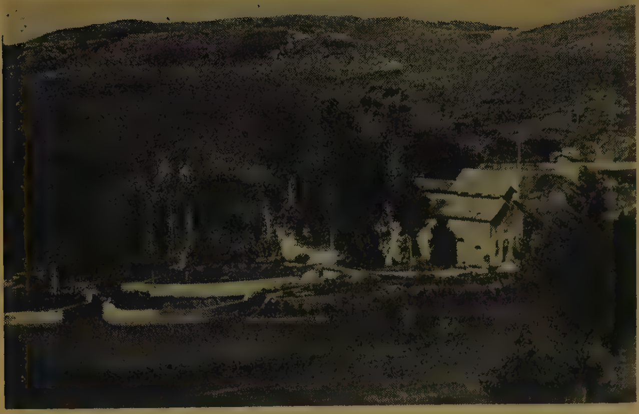

Figure 2. Shilungpah, first hydroelectric plant in China, near Kunming, Yunnan Province

somewhat as it is in the United States, where the generating capacity is 70 per cent fuel and 30 per cent hydroelectric and the energy output is 64 per cent from fuel and 36 per cent from hydroelectric plants.

The need of coal for power generation and other industrial purposes makes it imperative for China to maintain control of those regions in which large reserves exist to insure the future industrial development necessary for her economic betterment.

Only very limited quantities of petroleum have been found in China. The geological explorations to date indicate that oil fields exist in a region which begins in Sinkiang Province in the west, extends through Kansu, and terminates in Shensi Province on the east. The explorations have not been extensive enough to determine the oil reserves.

The most promising oil field is in Kansu Province north of the Chilien Mountains and on the Gobi Desert. This field was opened by the Kansu Oil Production and Refining Administration in 1941. Lack of adequate machinery during the war combined with negligible transportation facilities and remoteness from centers of population have retarded development. Lack of transportation and its high cost has made it practically impossible to utilize the small production. In 1944 truck transportation of petroleum products from the Kansu field was supplemented by goatskin rafts, which were floated down the Chialing River from Kwangyuan to Chungking.

Because of the extreme shortage of petroleum products during the war years the fuels used in internal combustion engines, including trucks and motor cars, consisted for the most part of gas from charcoal generators, grain alcohol, and fuels manufactured from vegetable and nut oils of various kinds including tung oil.

In the future the demands for petroleum products in China apparently will be so great in comparison with the national production that petroleum fuels probably will not be used extensively to generate electric energy.

Natural gas is available in limited quantities in certain areas but the present known supply is not sufficient to be of importance for the generation of electric energy. Some of the most important gas wells are in Szechwan Province in the Tzeliutsing salt well district. In this area there are 242 wells producing gas only and 166 producing brine and gas. The gas from these wells is sufficient to evaporate approximately one half of the brine for an annual production of 250,000 metric tons of salt.

HYDROELECTRIC POWER

Shilungpah was the first hydroelectric power development in China. It was built on the Mantis River by German engineers in 1910. Kunming Lake is the source of the Mantis River and serves as a storage reservoir to regulate the flow at the plant. The power site is in Yunnan Province approximately 30 kilometers (18.6 miles) southwest of Kunming and is 10 kilometers (6.2 miles) by trail from the Burma Road. A general view of the project is shown in Figure 2.

An interesting development is the Lower Tsing Yuen Tung plant. It is designed to operate with a head of 43 meters (141 feet) and develop 2,880 kw with four 720-kw units. The turbines and generators were ordered, two from England early in 1940 and two from the United States in 1941. The British equipment was delivered in Rangoon just before the fall of Burma and in spite of vigorous efforts to move it into China all of the equipment was lost except one turbine runner and some switchboard parts. With the turbine runner as a nucleus the Chinese engineers designed and built two turbines that were connected directly to a 2,000-kw rewound unit from a frequency-changer set. With this improvised generating unit the plant was put in operation in Jan-

Table III. Power Plants Constructed in Free China During World War II

Province	City	Constructing Agency	Kilowatts Capacity
Hunan	Henyang	National Resources Commission	1,000
	Chenchi	National Resources Commission	500
Kansu	Lanchow	Province and National Resources Commission	500
	Tsenshui	Province and National Resources Commission	200
Kwangsi	Liuchow	Province and National Resources Commission	2,000
Kweichow	Kweiyang	Province and National Resources Commission	500
Sikang	Sichang	National Resources Commission	100
Szechwan	Changshow	National Resources Commission	2,876
	Ipin	National Resources Commission	6,000
	Luhsien	National Resources Commission	2,000
	Tzeliutsing	National Resources Commission	500
	Wanhsien	Province and National Resources Commission	500
	Wutungchiao	National Resources Commission	2,500
Tsinghai	Sining	Province and National Resources Commission	200
Yunnan	Kunming	National Resources Commission	2,000
	Yanglin	National Resources Commission	2,000
Total			23,376

uary 1944. A unique feature of the plant is that it is built in a natural cave in the rock cliff beside Lower Tsing Yuen Falls, as a protective measure against aerial bombing.

Hydroelectric plants having a generating capacity of 6,081 kw or 0.88 per cent of the total installed capacity constitute the water power development in China to the end of World War II.

Water power resources are being studied by the National Hydroelectric Power Survey. This organization has completed preliminary surveys on 37 rivers in 11 provinces and the work is continuing. During 1944 Doctor J. L. Savage, chief designing engineer of the United States Reclamation Bureau, studied the potential hydroelectric power sites in China under a co-operative plan between the Chinese government and the United States Department of State.

Accurate stream flow records, over a period of years, are not available on any but the largest rivers, where they have been kept as an aid to navigation. Lack of this information is a great handicap in the design of hydroelectric plants where flow-duration data play such an important role in the design of economical installations.

Completed surveys show that China has some of the outstanding potential water power sites in the world. A site that has attracted particular attention is at the mouth of the Yangtze Gorge near Ichang in Hupeh Province.

An analysis of the data collected by the Yangtze River Commission and the Chinese Maritime Commission over a period of 22 years from 1904 to 1926 make it possible to construct an unregulated flow-duration curve for the Yangtze at Ichang. This flow-duration is shown by curve 1 of Figure 3. The unregulated flow of the river is 100,000 cubic feet per second 95 per cent of the time and 480,000 cubic feet per second 50 per cent of the time. A minimum flow of 47,000 cubic feet per second occurred in 1909 and a maximum flood of 2,100,000 cubic feet per second in 1921. Because of the very deep and relatively narrow gorge through which the Yangtze flows for hundreds of miles above Ichang, it is anticipated that it will be feasible to construct a dam at that point which will provide a head of 400 feet without flooding an unreasonable amount of tillable land. Using a 400-foot head and an over-all efficiency of 80 per cent from falling water to power delivered at the bus bars the flow-duration curve can be made to show that the unregulated flow of the Yangtze at Ichang is capable of generating 2,700,000 kw 95 per cent of the time and 12,900,000 kw 50 per cent of the time. The magnitude of this potential generating capacity is recognized when compared with the ultimate installed capacity of 1,317,500 kw at Boulder Dam and 1,944,000 kw at Grand Coulee.

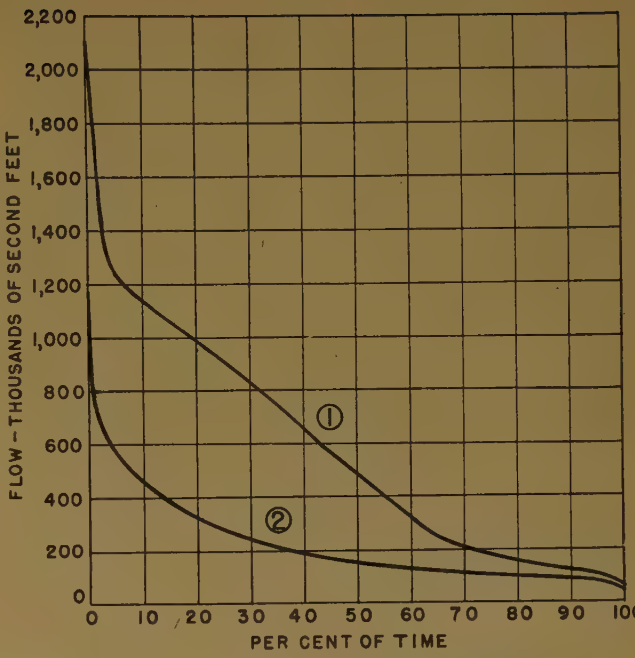

Figure 3. Unregulated flow-duration curves

1—Yangtze River at Ichang, years 1904 to 1926
Minimum flow 47,000 second-feet in 1909
Maximum flood 2,100,000 second-feet in 1921
2—Columbia River at Bonneville, years 1879 to 1933
Minimum flow 40,000 second-feet
Maximum flood 1,170,000 second-feet in 1894

For comparative purposes the unregulated flow-duration curve for the Columbia River at Bonneville, Oreg., have been plotted as curve 2 on Figure 3. The Columbia River was selected for comparative purposes because it has a large uniform flow and its developed and potential water power are well known.

A head of 400 feet at Ichang would back the water up the Yangtze Gorge approximately 400 miles to Chungking and greatly improve the navigation of this very treacherous portion of the river. It would provide irrigation water by gravity to an estimated 10 million acres on the Yangtze plain and power for pumping water on a very large additional area. Approximately 95 million people live within a radius of 300 miles of the project, therefore it would be possible to serve a very large population within reasonable transmission distance. It must be pointed out, however, that this large population is making very little use of electric energy in the area at present. A circle with its center at Ichang and a radius of 300 miles will include only an existing installed capacity of 38,100 kw, or approximately 1.4 per cent of the firm capacity and less than 0.4 per cent of the proposed installed capacity for the Ichang development. Because of this small use of electric energy in the area it is apparent that if the Ichang plant is to be built in the near future the problem is not only one of financing the design and construction of the project but also the development of a load to utilize the output.

During their occupation and control of Manchuria the Japanese made two large hydroelectric power developments, one on the Sungari River near Kirin and the other on the Yalu River at Shojo. One of these developments has a capacity of 450,000 kw and the other 360,000 kw, which makes the total hydroelectric development 810,000 kw. In addition to these hydroelectric plants there were 721,500 kw of installed capacity in fuel plants which makes the total generating capacity for Manchuria 1,531,500 kw. In accordance with the decisions at the Cairo Conference, the Chinese government planned to use this power and the industrial development in Manchuria as a nucleus for the industrial development of China in the postwar period. Since the Japanese surrender on September 2, 1945, these plans have been blighted by the stripping of industrial plants and the removal of a large part of the installed generating capacity.

POWER TRANSMISSION

Long distance electric power transmission has been used very little in China because in the past more than 99 per cent of the installed generating capacity has been in fuel plants built near the load centers. Difficulties encountered in fuel transportation and the high cost of its transportation recently have resulted in the construction of mine mouth plants and others on streams where coal can be transported by water. This trend, together with the development of hydroelectric power, will make it necessary to increase the use of long distance transmission lines in future power developments.

The longest transmission line in China, known as the Tsin-I line, was completed in 1944. It transmits power from the Ipin steam plant on the Yangtze River to Tzeliutsing in the heart of the salt producing district of Szechwan Province, a distance of 87 kilometers (54 miles). This line was built because the high cost of coal (April 1944 cost $6,500 in Chinese national currency per metric ton of which $4,000 was for transportation) delivered in Tzeliutsing from the Wei Youan Coal Mine, a distance of 37 kilometers (23 miles), made the cost of electric energy generated in the Tzeliutsing plant excessive. Coal delivered to the Ipin plant by water and a short tram haul was $3,000 Chinese national currency per metric ton at that time or approximately one half the cost in Tzeliutsing.

The transmission voltages that have been standardized tentatively by the electricity department of the National

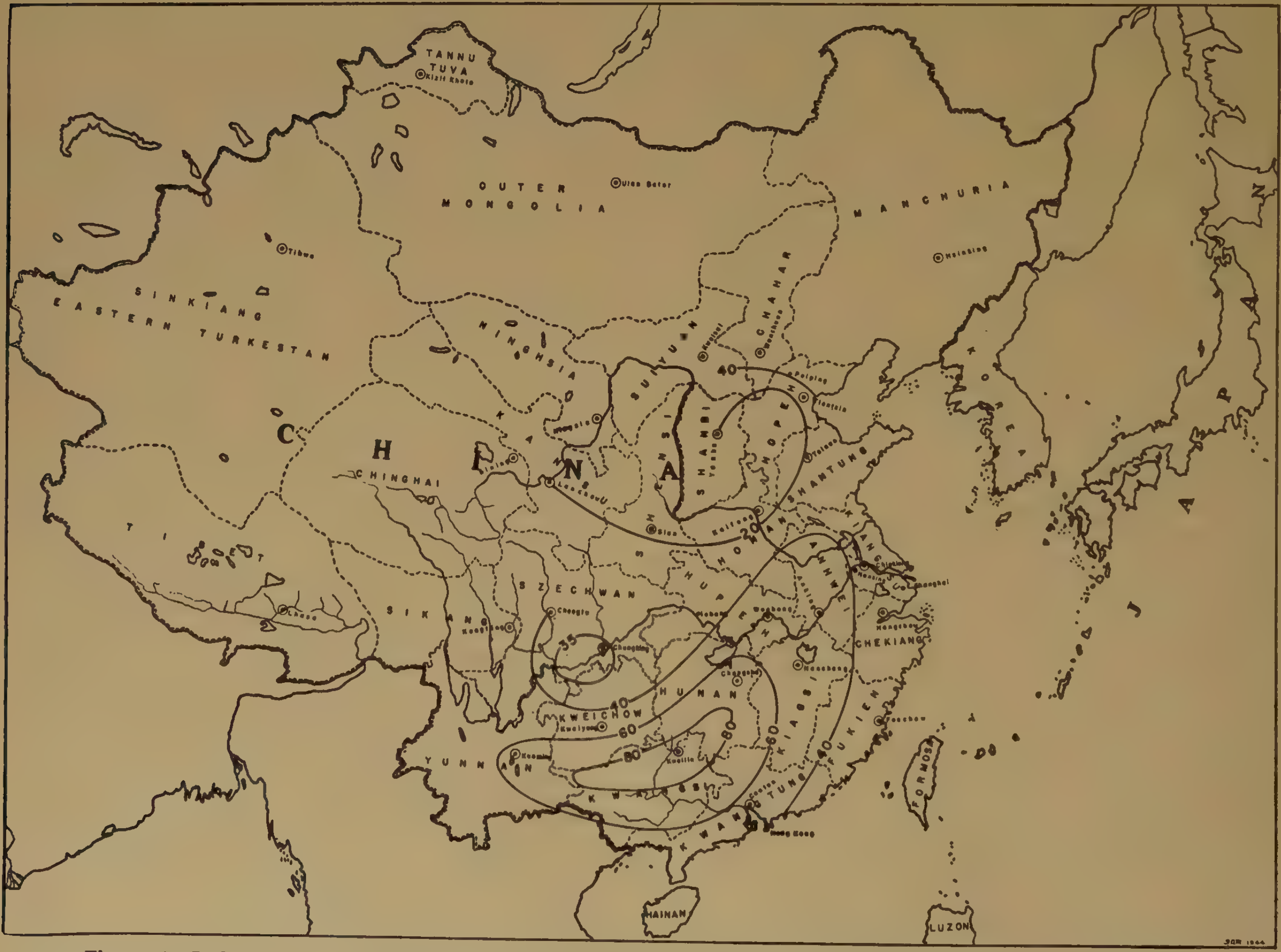

Figure 4. Isokeraunic map showing average number of days per year on which thunderstorms occur in China

Resources Commission for future transmission lines in China are 220 kv, 132 kv, 66 kv, and 33 kv.

The scarcity of wood poles, their high cost, and their relatively short life probably will result in the use of steel towers and structures for most of the transmission line construction in China.

POWER DISTRIBUTION

Distribution voltages have been standardized tentatively by the electricity department of the National Resources Commission. Large cities and rural districts will be served by 33-kv and 13.2-kv lines. The principle primary distribution voltage for general use will be 6.6 kv and the secondary service voltages will be 380 and 220 volts for small industries, commercial, and domestic consumers. Secondary service voltages are obtained from 3-phase Y-connected transformers with solidly grounded neutral and 4-wire secondary circuits having 380-volts line-to-line and 220 volts line-to-neutral. Combination power and lighting service obtained in this manner is economical in first cost, especially in lightly loaded districts, but is objectionable for the following reasons:

1. Power and lighting services are taken from the same transformers thus resulting in bad voltage regulation and lamp flicker.
2. The voltage above ground on lighting fixtures and domestic appliances is 220 volts which increases the probability of fatal accidents and also the fire hazard.
3. Standard domestic appliances and equipment made in the United States cannot be used directly on the service lines.

LIGHTNING PROTECTION

In the design and protection of electric power systems, especially transmission and distribution lines, it is important to have data regarding the frequency of lightning storms and their geographical distribution. These data can be shown best by an isokeraunic map drawn with contours of equal annual lightning storm frequency. As far as can be learned, no such map had been made for China prior to 1944. To make the existing lightning storm data, collected by the Central Meteorological Institute, readily available a map showing the isokeraunic contours for China was prepared in February 1944. This map is shown in Figure 4. The thunderstorm frequency contours are based on the number of thunderstorms occurring annually at 26 observation stations in different parts of China and over varying periods of observation ranging from 1 to 11 years. The years of observation and number of stations are not large enough to establish the isokeraunic contours accurately, however, it is believed the map will be useful until more extensive data are available.

Table IV. Coal Reserves and Production in China

Province	Reserves (Thousands of Metric Tons)	Annual Production (Thousands of Metric Tons)	Year
Anhwei	347,000	633	1934
Chahar	504,000	202	1934
Chekiang	101,000	250	1934
Fukien	500,000		
Honan	6,624,000	2,130	1934
Hopei	3,071,000	7,739	1934
Hunan	1,793,000	1,050	1940
Hupei	440,000	458	1934
Kansu	1,500,000	98	1940
Kiangsi	969,000	340	1940
Kiangsu	217,000	267	1934
Kwangsi	300,000	30	1940
Kwangtung	421,000	338	1934
Kweichow	1,549,000	360	1940
Ninghsia	488,000	15	1934
Shansi	127,127,000	2,700	1934
Shantung	1,639,000	3,504	1934
Shensi	71,950,000	322	1940
Sikang		32	1940
Sinkiang		100	1930
Suiyuan	417,000	58	1934
Szechwan	9,874,000	3,280	1940
Yunnan	1,627,000	202	1940
Total	231,458,000	24,108	

The maximum average number of days per year on which thunderstorms occur that have been observed in China is 85 in Hunan Province. This is slightly less than the maximum average for the United States, which is 90 in Florida. The minimum average is 14 in Anhwei Province as compared with a minimum average of one on the California coast in the San Francisco Bay region. It may be concluded that, from the standpoint of storm frequency, the lightning protection problems in China are comparable to those in the United States. However, comparatively little is known regarding the severity of the storms.

STANDARD FREQUENCY

In 1929 a commission adopted 50 cycles as the standard frequency for the electric power supply systems in China. Some of the major factors influencing the choice of frequency at that time were the following:

1. Many of the nations of the world were using 50 cycles as a standard frequency, notably Great Britain, Germany, France, Italy, Russia, Sweden, and Japan.
2. There was more 50-cycle than 60-cycle equipment installed in China.
3. Inasmuch as a larger number of nations were using 50 cycles than 60 cycles, China would have a wider choice of markets from which to purchase equipment.
4. Transmission and distribution line reactances are lower on 50 cycles than on 60 cycles, therefore the voltage regulation and stability of the system should be better.
5. Fifty cycles is an even multiple of 25 cycles which is the frequency generally used for a-c railway electrification.

On July 15, 1944, a memorandum was submitted to the Chinese government recommending that the subject of the future frequency standard be studied critically by a competent commission of technical and business men. Some of the basic reasons for the recommendation were:

1. The fact that many nations of the world are using 50 cycles is not conclusive evidence that 50 cycles is the best frequency for

China to adopt at the beginning of her electrical and industrial development. Nations using 50 cycles made their choice many years ago and now find it impractical to change, regardless of the merit of such a change.

2. The existence of more 50-cycle than 60-cycle equipment in China does not justify the adoption of a frequency standard that will require heavier equipment using more critical copper and steel and which is more expensive.

3. Existing electric equipment in China is insignificant in comparison with future requirements for any significant degree of industrialization, therefore, it should not determine the future frequency standard.

4. The average age of the major generating equipment in China is 14.2 years and the weighted-average age based upon kilowatt rating is 15.3 years. Using 30 years as the average age of steam-driven generating equipment for purposes of depreciation, the existing equipment, in addition to being an insignificant part of the probable future requirements, has served 50 per cent of its useful life.

5. Lower transmission and distribution line reactance at 50 cycles than at 60 cycles becomes less important when the line reactance is compensated by the introduction of series capacitance which is the present trend in long distance transmission.

6. The fact that 50 cycles is an even multiple of 25 cycles, the latter being the most commonly used frequency for a-c railway electrification, does not justify compromising the frequency standard of a nation because 25 cycles can be obtained from a 60-cycle power source without excessive investment or energy cost.

FUTURE POWER DEVELOPMENT

Two power development programs are planned by the electricity department of the National Resources Commission in the postwar period. They are designated as the Nucleus Plan and the Five Year Plan. The Nucleus Plan is that part of the Five Year Plan to be carried out as rapidly as possible after cessation of hostilities. It involves the installation of 840,000 kw of steam generating capacity and 280,000 kw of hydroelectric capacity making a total of 1,120,000 kw in nine provinces. The Five Year Plan contemplates the installation of 1,410,000 kw in steam plants and 578,000 kw in hydroelectric plants, which makes the total for five years 1,988,000 kw.

The success or failure of these plans obviously will depend upon the outcome of the present civil war and the economic stability that can be established. Some idea of the economic problems involved is indicated by the fact that the July 1946 price index was 4,494 times the June 1937 value and the August 30, 1946, official rate of telegraphic transfer was $3,350 Chinese national currency to $1 United States currency.

Table V. Coal Reserves and Production in Manchuria

Province	Reserves (Thousands of Metric Tons)	Annual Production (Thousands of Metric Tons)	Year
Heilungkiang	1,017,000	405	1934
Jehol	614,000	356	1934
Kirin	1,143,000	411	1934
Liaoning	1,836,000	10,656	1934
Total	4,610,000	11,828	

Chinese Power Plant

TECHNICAL ORGANIZATION

For centuries China has honored her scholars for their chirography, literature, philosophy, and art, and recently she has added honors for achievements in the applied fields of learning such as science and engineering. This recognition is evidenced by the number of high government offices held by men trained in science and engineering and also the importance attached to scientific and engineering organizations, such as Academia Sinica and the Chinese Institute of Engineers. The Chinese Institute of Engineers is an organization of all of the engineering societies in the major fields of engineering. It is now in its 15th year and constantly is growing in prestige and importance. An annual convention of the institute is held at which all of the member societies hold their annual meetings. The 12th annual convention of the institute was held in Kweilin, Kwangsi Province, October 21 to 24, 1943, under the presidency of Doctor Wong, Wen-hao, minister of economic affairs and chairman of the National Resources Commission and who is now vice-president of the executive yuan. This meeting was attended by more than 1,200 engineers from all parts of Free China. It was estimated that 80 per cent of those attending had received either academic or industrial training or both in the United States.

One of China's great needs is trained and experienced engineers for rehabilitation and industrial development. She is endeavoring to meet this demand by training men in her own colleges and universities and also by sending men abroad for both educational training and industrial experience.

INSTITUTE ACTIVITIES

Largest Technical Program
Set for Winter Meeting, January 27-31

The winter meeting to be held in New York, N. Y., January 27–31, 1947, will feature a broad program of professional and social activities. The technical program, the largest in the history of the Institute, is a manifestation of the effort of the AIEE to cover the technical field completely. This is evidenced further by the holding of a special conference on the technical activities. The program is comprised of 26 technical sessions, presenting about 100 papers, and 16 technical conferences. As an innovation, the Edison, John Fritz, and Hoover Medals will be presented in general sessions in the afternoons, co-ordinated with technical sessions appropriate to the fields of achievements of the medalists. A group of inspection trips also has been arranged closely allied with the subject matter of several sessions. On the social side there will be a smoker, theater tickets for out-of-town members, and special entertainment for the women. Meeting headquarters will be in the Engineering Societies' Building.

NONMEMBER REGISTRATION REQUIRED

Members should register in advance by filling in the advance registration card with the mailed announcement. A registration fee of $2 will be charged all nonmembers, except Student Members, and the immediate families of members. The nonmember registration fee will be enforced strictly by requiring a showing of badges for admission to all technical sessions and conferences.

HOTEL ACCOMMODATIONS

The hotel situation in the metropolitan area is still acute. Members should make their plans early and make all arrangements for reservations directly with the hotel preferred. The Institute has no connections with any of the hotels and therefore cannot undertake to make any reservations.

SMOKER

All arrangements are well under way for that very popular "Smoker" which will be held as usual on Tuesday night, January 28, at the Hotel Commodore. Chairman C. T. Hatcher advises that the evening will open with a cocktail hour at 5:30 p.m. in the West Ballroom, with dinner and show to follow. Tables for dinner for six, eight, and ten persons will be available to the maximum capacity of the Grand Ball Room. Price of the tickets will be $7.50 per person. Though every effort will be made to meet all demands for tickets, the physical limits of the room have made this difficult for several years past. Reservations should be in early.

DINNER DANCE CANCELLED

Because of the greatly increased cost that would be involved in arranging a dinner dance and maintaining the quality of the affair for which the winter meeting has been noted, the committee has decided to cancel the dinner dance this year.

LADIES ACTIVITIES

The ladies entertainment committee, working under the chairmanship of Mrs. James F. Fairman, has arranged for two affairs which should prove of great interest to all women attending the winter meeting. They are as follows:

1. *Sightseeing Trip and Tea—Tuesday, January 28 at 2 p.m.* Busses will be available for an extensive sightseeing trip around New York City stopping at the Tavern on the Green in Central Park for tea at 4.30 p.m. Tickets are $1 per person.

2. *Luncheon and Bridge—Wednesday, January 29 at 12.30 p.m.* A luncheon will be served at the Engineering Woman's Club, 2 Fifth Avenue, with a bridge party to follow. Tickets are $1 per person.

Members should arrange for early reservations for women who will be attending the meeting, as accommodations are limited.

THEATER TICKETS

In the effort again to meet the demands of out-of-town members attending the winter meeting for tickets to popular New York shows, the theater ticket committee under H. H. Heins is negotiating the purchase of blocks of tickets to a selected group of the most popular shows. These tickets will be obtained for various performances throughout the week. A schedule of shows with prices of tickets will be available in later notices of the meeting. Out-of-town members will be given preference on all reservations.

INSPECTION TRIPS

The inspection trips committee under R. T. Oldfield has set up an interesting and comprehensive schedule of inspection trips co-ordinated as far as possible with the various technical sessions. The present schedule is as follows:

Monday, January 27
CBS Television Tour
Visitors may witness the sending and receiving of images

Tuesday, January 28
Grumman Aircraft Company, Hicksville, L. I.
Leave Pennsylvania Station by Long Island Rail Road (See production line methods in manufacture of latest types of both military and commercial planes)
Bell Laboratories, Summit, N. J.
Leave headquarters by bus at 1:00 p.m., return 6:30 p.m. Recent developments in metallurgical research, rubber, synthetic crystals, and radar. Special arrangements may be considered for the admission of noncitizens by written request addressed to "Inspection Trips Committee, American Institute of Electrical Engineers, 33 West 39th Street, New York 18, N. Y." Such applications should be mailed not later than January 15, 1947.

(*Continued on page 79*)

Tenative Schedule of Events

Monday, January 27

9:30 a.m.	Light traction Automatic stations Metallic rectifiers Conference of Student Branch counselors
2:00 p.m.	Electronics Electric railways Conference on applied mathematics Conference on technical activities

Tuesday, January 28

9:30 a.m.	Protective devices Electronic instruments Diesel-electric locomotives Conference on power supply for resistance welding Servomechanisms
1:45 p.m.	General session Edison Medal presentation
2:00 p.m.	Women's sightseeing trip and tea
2:30 p.m.	Television and demonstrations Power relays Instruments and measurements Resistance welding Conference on statistical methods
5:30 p.m.	Smoker at Hotel Commodore

Wednesday, January 29

9:30 a.m.	Conference on energy sources Industrial control devices Conference on distribution circuit protection Conference on some new electronic devices and methods
12:30 p.m.	Women's luncheon and bridge
1:45 p.m.	General session John Fritz Medal presentation
2:30 p.m.	Symposium on limitations of light production Hydroelectric systems Symposium on rural telephone facilities Conference on industrial voltages Conference on electric machinery

Thursday, January 30

9:30 a.m.	Applications in the textile industry Conference on aircraft safety Basic sciences Conference on interconnected systems
1:45 p.m.	General session Hoover Medal presentation
2:30 p.m.	Conference on large-scale computing devices Industrial power applications Conference on aircraft safety Conference on testing telephone receivers and transmitters

Friday, January 31

9:30 a.m.	Symposium on lightning Electric machinery Symposium on grounding portable electric equipment
2:00 p.m.	Power transmission Industrial instrumentation and control Electric machinery Communications components and techniques

Tentative Program, AIEE Winter Meeting,

Monday, January 27

9:30 a.m. Light Traction

Address: Rapid Transit Plans for New York. **Major General Charles P. Gross**, chairman, Board of Transportation, New York City Transit System

47-43. Modern Car Equipment for New York City's Subway System. **B. F. Cordts**, New York City Transit System

47-44. Special 10-Car Train for the New York City Transit System. **J. J. Sinclair**, New York City Transit System

47-45. Can the Trolley Coach Compete Economically With the Gas or Diesel Bus Where No Overhead Facilities Exist? **J. H. Gauss**, General Electric Company

9:30 a.m. Automatic Stations

47-51. Automatic Control of Air Switches for Line Sectionalizing and Load Transfer. **F. W. Rich, M. S. Kirwen**, the Commonwealth and Southern Corporation. Presentation by title

47-54. Automatic Switching Schemes for Capacitors. **W. H. Cuttino**, Westinghouse Electric Corporation

47-55. The Economics of Using Capacitors in Amounts to Require Automatic Switching. **J. W. Butler**, General Electric Company

9:30 a.m. Metallic Rectifiers

47-34. The Physics of Electronic Semiconductors. **G. L. Pearson**, Bell Telephone Laboratories, Inc.

47-25. Higher-Voltage Copper-Oxide Rectifiers. **I. R. Smith**, Westinghouse Electric Corporation

47-26. Electrical Characteristics of the Junction in a Simplified Selenium Rectifier Cell. **S. J. Angello**, University of Pennsylvania

47-27. Automatically Controlled Copper-Oxide Rectifiers for Electroplating and Anodizing Applications. **J. J. Buckley**, General Electric Company

CP.** Discussion of Report on Proposed Definitions for Metallic Rectifiers. **Subcommittee on metallic rectifiers**

CP.** Report on Bibliography of Metallic Rectifiers. **Subcommittee on metallic rectifiers**

9:30 a.m. Conference of Student Branch Counselors

Demonstration of a film and talk which might be used before Student Branches in support of membership efforts. **Tomlinson Fort**, chairman, membership committee

2:00 p.m. Electronics

47-68. The Shunt Tube Control of Thyratron Rectifiers. **J. A. Potter**, Bell Telephone Laboratories, Inc.

47-69. Electronic Constant-Current Motor Systems. **O. W. Livingston**, General Electric Company

CP.**. Sealed Ignitrons for Power Rectifiers. **W. E. Pakala, C. R. Marcum**, Westinghouse Electric Corporation

47-71. Arc-Back Testing of Graphite. **W. E. Pakala, C. J. Cucullu**, Westinghouse Electric Corporation

2:00 p.m. Electric Railways

47-8. Developments in Current Collectors for High-Speed Service. **B. F. Langer**, Westinghouse Electric Corporation

47-41. Some Recent Developments in the Presidents' Conference Committee Car. **S. B. Cooper**, Westinghouse Electric Corporation

47-42. Recent Developments in Track Brakes and Drum Brakes for Presidents' Conference Committee Cars. **S. J. Vouch**, General Electric Company

● **PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.**

● **ABSTRACTS of most papers appear on pages 84–93 of this issue and pages 581–3 of the December issue.**

● **PRICES and instructions for procuring advance copies of these papers accompany the abstracts. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.**

● **COUPON books in five-dollar denominations are available for those who may wish this convenient form of remittance.**

● **THE PAPERS regularly approved by the technical program committee ultimately will be published in "Proceedings" and "Transactions"; essential substance of many will appear in "Electrical Engineering."**

47-53. Investigation of Silicone Insulation on High-Temperature Railway Motor. **George Grant III, T. A. Kauppi**, Dow-Corning Corporation; **G. L. Moses**, Westinghouse Electric Corporation

2:00 p.m. Conference on Applied Mathematics

2:00 p.m. Conference on Technical Activities

Tuesday, January 28

9:30 a.m. Protective Devices

47-59. The Interruption of Charging Current at High Voltage. **W. M. Leeds, R. C. Van Sickle**, Westinghouse Electric Corporation

47-6. Resistors for 138-Kv Cable Switching. **E. K. Sadler**, Kelman Electric and Manufacturing Company; **T. M. Blakeslee**, Department of Water and Power, City of Los Angeles

47-50. An Improved Automatic Circuit Recloser. **J. M. Wallace**, Westinghouse Electric Corporation

47-60. Sectionalizing and Internal Transformer Fusing on Rural Power Circuits. **B. O. Watkins**, Rural Electrification Administration

9:30 a.m. Electronic Instruments

CP.** The Influence of Electronics on Industrial Instrumentation. **H. D. Middel**, General Electric Company

47-86. Pulse Echo Measurements on Telephone and Television Facilities. **L. G. Abraham, A. W. Lebert, J. B. Maggio, J. T. Schott**, Bell Telephone Laboratories, Inc.

47-84. A Magnetic Compass With Cathode-Ray Sensing Element. **W. H. Kliever, R. R. Syrdal**, Minneapolis-Honeywell Regulator Company

47-85. Electronic Null Detectors for Use With Impedance Bridges. **H. W. Lamson**, General Radio Company

47-13. The Cathode-Ray Spectrograph. **Rudolf Feldt, Carl Berkley**, Allen B. DuMont Laboratories, Inc.

9:30 a.m. Diesel-Electric Locomotives

47-36. A 3,000-Horsepower Diesel-Electric Locomotive for the Seaboard Air Line Railway. **D. R. Staples**, Baldwin Locomotive Works; **T. L. Weybrew, C. A. Atwell**, Westinghouse Electric Corporation

47-37. Developments in Diesel-Electric Traction-Generator Excitation Control Systems. **C. A. Brancke, G. M. Adams**, General Electric Company

47-38. Braking Resistors and Control for Diesel-Electric Locomotives. **E. F. Weiser**, General Electric Company

47-39. A Power Plant Regulating System for Diesel-Electric Locomotives. **C. B. Lewis**, General Electric Company

47-40. Developments in Control Systems for Diesel-Electric Locomotives. **M. D. Henshaw**, General Electric Company

9:30 a.m. Conference on Power Supply for Resistance Welding

CP.** Resistance Welding, a Beneficial Load. **N. J. Roberts**, Ohio Public Service Company

CP.** Co-operative Approach to Power Supply for Resistance Welders. **H. W. Tietze**, Public Service Electric and Gas Company

CP.** Our Methods of Servicing Resistance Welder Loads. **R. E. Young, J. E. Renbush**, Public Service Company of Northern Illinois

CP.** Application Engineers Role in Insuring Adequate Power Supply for Resistance Welders. **K. W. Ostrom**, National Electric Welding Machines Company

CP.** New Fields for Stored Energy Welding. **A. C. Johnson**, Progressive Welder Company

9:30 a.m. Servomechanisms

47-7. The Application of Lead Networks and Sinusoidal Analysis to Automatic Control Systems. **G. J. Schwartz**, Arma Corporation

47-12. A Comparison of Two Basic Servomechanism Types. **Herbert Harris**, Sperry Gyroscope Company, Inc.

47-15. Dimensionless Analysis of Servomechanisms by Electrical Analogy—II. **G. D. McCann**, California Institute of Technology; **S. W. Herwald**, Westinghouse Electric Corporation

47-52. Laboratory Aids for Electromechanical System Development. **G. C. Newton, Jr., W. T. White**, Sperry Gyroscope Company

1:45 p.m. General Session

Edison Medal Presentation

2:30 p.m. Television and Demonstrations

47-72. Television Equipment for Broadcast Stations. **W. L. Lawrence**, Radio Corporation of America

47-73. Postwar Television Receiver Design. **D. W. Pugsley**, General Electric Company

CP.** Color Television Receivers. **P. C. Goldmark, G. R. Tingley**, Columbia Broadcasting System

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47-74. Television Network Facilities. **L. G. Abraham**, Bell Telephone Laboratories, Inc.; **H. I. Romnes**, American Telephone and Telegraph Company

47-75. A New Microwave Television System. **J. F. Wentz, K. D. Smith**, Bell Telephone Laboratories, Inc.

2:30 p.m. Power Relays

47-65. Grounding of Instrument Transformer Secondary Circuits. **Working group on grounding of instrument transformer secondary circuits**

CP.** Simplicity on Transformer Protection. **Relay subcommittee**

47-66. Fundamental Basis for Distance Relaying. **W. A. Lewis, L. S. Tippett**, Illinois Institute of Technology

47-67. Experience With Single-Pole Relaying and Reclosing on a Modern 132-Kv System. **J. J. Trainor, C. E. Parks**, Public Service Company of Indiana, Inc.

2:30 p.m. Instruments and Measurements

47-104. Air-Borne Magnetometers for Search and Survey. **E. P. Felch, W. J. Means, T. Slonczewski**, Bell Telephone Laboratories, Inc.: **L. H. Rumbaugh**, Naval Ordnance Laboratory, **L. G. Parratt**, Cornell University; **A. J. Tickner**, Western Electric Company, Inc.

47-11. The Calibration of Ignition Crest Voltmeters. **W. L. Davis**, Battelle Memorial Institute; **C. E. Warren**, Ohio State University

47-22. Advancements in the Design of Long-Scale Indicating Instruments. **R. M. Rowell, N. P. Millar**, General Electric Company

47-23. Measurement of High Q Cavities at 10,000 Megacycles. **R. W. Lange**, Bell Telephone Laboratories, Inc.

47-24. A Polyphase Thermal Ampere Demand Meter. **A. J. Petzinger**, Westinghouse Electric Corporation

2:30 p.m. Resistance Welding

47-61. Voltage Changes Due to Resistance Welding Loads. **I. B. Johnson, H. A. Peterson, C. M. Rhoades**, General Electric Company

47-62. The Voltage Drop in the Welder Throat Loaded With Ferromagnetic Materials. **G. M. Stein**, Westinghouse Electric Corporation

47-63. Electrical Characteristics of Resistance Welding Tools. **E. M. Callender**, The Budd Company

47-64. Functionalized Resistance Welding Control. **C. B. Stadum, W. E. Large, E. C. Hartwig**, Westinghouse Electric Corporation

2:30 p.m. Conference on Statistical Methods

CP.** The American Society for Quality Control—Its Objectives and Its Progress to Date. **George D. Edwards**, president, American Society for Quality Control

CP.** Statistics Applied to Consumer Goods. **E. E. Folsom**, General Electric Company

CP.** Application of Statistical Methods in Industry. **A. J. Winterhalter**, Colonial Radio Corporation

5:30 p.m. Smoker, Hotel Commodore

Wednesday, January 29

9:30 a.m. Conference on Energy Sources

The first of a series of conferences on methods of producing electric power will be sponsored by the committee on basic sciences. The great impetus given to new methods of supplying electric power by developments in nuclear energy has suggested that all known methods of producing electric power should be reviewed in the light of present-day knowledge. For purposes of classification, the known means of electric energy generation have been divided into the following ten classes: electromagnetic, thermoelectric, electrostatic, electrochemical, piezoelectric, contact electricity, emission phenomena, pyroelectric, magneto strictive, and earth potential. At this conference a survey paper will describe the various phenomena and three of the ten classes, namely, emission phenomena, piezoelectric phenomena, and electrostatic phenomena, will be discussed by outstanding experts in their respective fields. At later conferences other phases of this problem will be discussed by well-known authorities.

CP.** A Survey of Methods of Producing Electric Power. **L. W. Matsch**, Armour Research Foundation

CP.** Emission Phenomena. **Doctor L. A. DuBridge**, president, California Institute of Technology

CP.** Piezoelectric Phenomena. **Doctor Walter G. Cady**, professor of physics, Wesleyan University

CP.** Electrostatic Phenomena. **John G. Trump**, associate professor of electrical engineering, Massachusetts Institute of Technology

9:30 a.m. Industrial Control Devices

47-17. Shading Coil Calculations for Single-Phase Magnets. **C. T. Evans**, Cutler-Hammer, Inc.

47-19. A Thrustor Lowering Control System for A-C Crane Hoists. **E. L. Schwarz-Kast**, Illinois Institute of Technology

47-20. Dynamic Braking by Self-Excitation of Squirrel-Cage Motor. **A. Srinivasan**, Illinois Institute of Technology; **M. A. Thomas**, New Mexico State College

47-21. Dynamic Braking of a Single D-C Series Motor. **J. D. Leitch**, The Electric Controller and Manufacturing Company

9:30 a.m. Conference on Distribution Circuit Protection, Construction, Service Continuity, and Fault Records

Distribution circuit protection practices and construction methods will be the subject of a conference which will emphasize the influence of these factors on the reduction of sutained faults on distribution systems. This conference is sponsored jointly by the relay subcommittee of the committee on protective devices and by the distribution subcommittee of the committee on power transmission and distribution. The service continuity requirements of distribution circuits are becoming more important because of the increased commercial, domestic, and rural uses of electricity. Outages other than those of a short duration may cause serious inconvenience especially where electric power is used for such purposes as cooking, heater control, milking machines, and milk cooling. Efforts to effect service improvements through reduction in the number of sustained faults have been concentrated sometimes on protection practices and other times on construction methods. A joint subcommittee with Mr. G. B. Dodds as chairman is studying the problem from both standpoints. Introductory conference papers will be presented, after which discussion from the floor will be invited. It is hoped to develop interchange of experience data, which also will be of value to the joint subcommittee in continuing its investigations. Methods of recording and correlating interruption data will be emphasized.

9:30 a.m. Conference on Some New Electronic Devices and Methods

1:45 p.m. General Sesion

John Fritz Medal Presentation

2:30 p.m. Symposium on Limitations of Light Production

2:30 p.m. Hydroelectric Systems

47-56. Testing Governor Performance on Electric Power Systems With Improved Instruments. **J. E. Allen**, Pennsylvania Water and Power Company; **W. B. Hess**, Safe Harbor Water Power Corporation

47-57. Automatic Control of Hydroelectric Generating Stations. **M. J. Brown, W. A. Derr**, Westinghouse Electric Corporation

47-58. Modern Bearing Pracitce for Vertical Water Wheel Generators. **C. M. Laffoon, R. A. Baudry**, Westinghouse Electric Corporation

CP.** Characteristics of Hydraulic Turbines That Effect Operating Efficiency. **J. F. Roberts**, Allis-Chalmers Manufacturing Company

2:30 p.m. Rural Telephone Facilities

47-80. A Carrier Telephone System for Rural Service. **J. M. Barstow**, Bell Telephone Laboratories Inc.

47-81. Application of Rural Carrier Telephone System. **E. H. B. Bartelink**, General Telephone Corporation; **L. E. Cook**, Ebasco Services, Inc.; **F. A. Cowan**, American Telephone and Telegraph Company; **G. R. Messmer**, Rural Electrification Administration

47-82. Joint Use of Pole Lines for Rural Power and Telephone Services. **J. W. Campbell**, American Telephone and Telegraph Company; **L. W. Hill**, Carolina Telephone and Telegraph Company; **L. M. Moore**, Rural Electrification Administration; **H. J. Scholz**, Commonwealth and Southern Corporation

CP.** Open-Wire Construction for Rural Telephone Lines. **C. G. Sinclair, Jr.**, American Telephone and Telegraph Company; **D. M. Barnes**, Associated Telephone Company, Ltd.; **F. V. Haskell**, Bell Telephone Laboratories, Inc.

47-83. Rural Radiotelephone Experiment at Cheyenne Wells, Colo. **J. H. Moore**, American Telephone and Telegraph Company; **P. K. Seyler**, The Mountain States Telephone and Telegraph Company; **S. B. Wright**, Bell Telephone Laboratories, Inc.

2:30 p.m. Conference on Industrial Voltages

CP.** Report of Subcommittee on Industrial Voltage Requirements. Presentation by a member of the subcommittee

CP.** Voltage Regulation for Industrial Systems. **R. C. R. Schulze**, American Gas and Electric Service Corporation; **D. L. Beeman**, General Electric Company; **H. G. Barnett**, Westinghouse Electric Corporation; **W. H. Dickinson**, Standard Oil Development Company

2:30 p.m. Electric Machinery

47-10. Simplified Graphical Method of Computing Thermal Transients. **Paul Narbutovskih**, Westinghouse Electric Corporation

47-9. The Dielectric Properties of Cellulose Insulation Impregnated With Semiconductor Liquids. **F. M. Clark**, General Electric Company

47-16. A Study of the Relative Severity of Steep Front Waves and Chopped Waves on Transformers, **F. J. Vogel**, Illinois Institute of Technology

Thursday, January 30

9:30 a.m. Applications in the Textile Industry

47-103. Power Distribution in Textile Plants. **J. D. McConnell**, Proximity Manufacturing Company

47-35-ACO.* Electric Equipment for 2-for-1 Twister. **E. C. Gwaltney, H. J. Burnham**, Saco Lowell Shops

(*Continued*)

Tentative Program, AIEE Winter Meeting

47-32-ACO.* Electric Drives for Textile Finishing Ranges. **R. B. Moore, H. C. Uhl,** General Electric Company

47-33. Electrification of the Cotton Industry in the South. **S. A. Bobe,** Westinghouse Electric Corporation

9:30 a.m. Conference on Aircraft Safety

1. Safety, History, and Requirements
Prepared discussion: *A.* Standards today. *B.* Present needs and requirements. *C.* Trends in operation and design. *D.* Evaluation of weight. *E.* Definition of failures.

2. Types of electrical failures
Prepared discussion: *A.* Loss of power source. *B.* Loss of power at important load center. *C.* Electric apparatus failures. *D.* Driven machine failures. *E.* Fire. *F.* Smoke. *G.* Hydraulic considerations.

3. Protection in the Electric System
Prepared Discussion: *A.* Definition of protection—(*a*) Preventative. (*b*) Consequence limiting. *B.* Power source protection—(*a*) Generators. (*b*) Leads. (*c*) Regulators. (*d*) Relays. *C.* Distribution system—(*a*) Cables. (*b*) Protective relays. (*c*) Automatic protective system. (*d*) Multiple channel or dual power supply. *D.* Utilization equipment—(*a*) Relays. (*b*) Design considerations. (*c*) Wiring connectors, installation.
(Continued in the afternoon)

9:30 a.m. Basic Sciences

47-1. Eddy Currents in Disks: Driving and Damping Forces and Torques. **A. D. Moore,** University of Michigan

47-18. A 60-Cycle Hysteresis Loop Tracer for Small Samples of Low-Permeability Material. **D. E. Wiegand, W. W. Hansen,** Illinois School of Technology

47-87. Machine Computation of Power Network Performance. **L. A. Dunstan,** Federal Power Commission

47-88. Effective Resistance of Isolated Nonmagnetic Rectangular Conductors. **H. B. Dwight,** Massachusetts Institute of Technology

47-2. Theory and Application of Complex Logarithmic and Geometric Mean Distances. **T. J. Higgins,** Illinois Institute of Technology

9:30 a.m. Conference on Interconnected Systems

47-4. Theoretical Approach to Speed and Tie-Line Control. **Robert Brandt,** New England Power Company

1:45 p.m. General Session

Hoover Medal Presentation

2:30 p.m. Conference on Large-Scale Computing Devices

This subject is at present of great interest to many prospective users in government, industry, and the universities. The development, both during and since the war, has been tremendous, so that, although many people are familar in a general way with the fact that such computers have been and will be made, the status and field of usefulness of the various types, and what to expect in the near future is largely a matter of speculation. For this reason the committee has arranged for the following talks by men from each of the six leading centers of digital computer development to cover (1) the present status of developments and (2) the probable future trends.

CP.** **Commander H. H. Aiken,** in charge of the automatic sequence-controlled calculator at the Cruft Laboratory, Harvard University

CP.** **Julian Bigelow,** chief engineer of the computer project at the Institute for Advanced Study, Princeton University

CP.** **J. W. Forrester**, in charge of a computer project at the Servomechanisms Laboratory, Massachusetts Institute of Technology

CP.** **J. C. McPherson,** director of engineering, International Business Machines Corporation

CP.** **T. K. Sharpless** of the Moore School of Electrical Engineering, University of Pennsylvania

CP.** **S. B. Williams,** consulting engineer, formerly with Bell Telephone Laboratories, Inc.

2:30 p.m. Industrial Power Applications

47-28. An Analysis of Motor Selection for Brass-Slab Rolling-Mill Service. **L. H. Berkley,** Engineer Training Center, Fort Belvoir, Va.

CP.** Aluminum Ore Distribution Systems. **R. T. Woodruff,** Aluminum Ore Company

47-31-ACO.* A Selective Grounding System. **E. Herzog,** United States Army Air Forces

47-29. An Extension of Impact Speed Drop Analysis. **F. E. Crever,** General Electric Company

47-30. Cathodic Protection of Steel Water Tanks Using Aluminum Anodes. **L. P. Sudrabin,** Electro Rust-Proofing Corporaton; **R. B. Mears,** Aluminum Company of America

2:30 p.m. Conference on Aircraft Safety (continued)

4. Application Considerations

47-14. An Integrated Control System for Aircraft D-C Generators. **A. T. McClinton,** Naval Research Laboratory

47-5. Parallel Operation of Aircraft Alternators Using Electronic Frequency Changers. **O. E. Bowlus, P. T. Nims,** Chrysler Corporation. Presentation by title

Prepared discussion: *A.* Environment—(*a*) Moisture. (*b*) Ventilation. (*c*) Altitude. (*d*) Temperature. *B.* Loading—(*a*) Load analysis. (*b*) Machine selection. (*c*) Duty cycles. (*d*) Ratings. *C.* Installation. *D.* Radio noise.

5. Safety Program

Prepared discussion: *A.* Practical specifications. *B.* Subcommittee report on systems guide. *C.*

(*Continued from page 75*)

Waterside Generating Station, 708 First Avenue, New York, N. Y.
Assemble at 708 First Avenue at 2:00 p.m.
(High pressure boilers, 600,000 pounds per hour steam at 925 degrees Fahrenheit and 1,400 pounds per square inch, four topping turbogenerators)

Wednesday, January 29
RCA Laboratories, Princeton, N. J.
Leave Headquarters by bus at 1:00 p.m., return at 6:30 p.m.
CBS Television Tour (Repeat of Monday trip)
Waterside Generating Station, 708 First Avenue, New York, N. Y. (Repeat of Tuesday trip)
Pennsylvania and New York Central Railroad Equipment Inspection
Leave headquarters by bus at 1:30 p.m.
(See latest types of cars designed to meet competitive transportation)

Thursday, January 30
CBS Television Tour (Repeat of Monday trip)
Waterside Generating Station, 708 First Avenue, New York, N. Y. (Repeat of Tuesday trip)

Those wishing to make inspection trips are urged to make arrangements and secure tickets as soon as possible after registering at the winter meeting in order that adequate transportation facilities may be provided.

Where busses are required, a nominal charge will be made to defray this expense.

ELECTRICAL SHOW

During the entire week of the winter meeting an electrical show will be in progress at the 71st Regiment Armory, Park Avenue and 34th Street, New York, N. Y. This show staged and managed entirely by the International Exposition Company should prove of great interest to all engineers. Among the many exhibits featured will be the following: Electronic signal circuits, new developments in instrumentation, insulation materials and plastics, generators, motors, batteries, switchgear, panelboard, and lighting equipment. Admission will be by ticket only; the show will not be open to the public. Tickets will be available at AIEE headquarters inspection trip desk.

Activities for Year Summarized by Committee on Planning and Co-ordination

At the beginning of the administrative year 1945–46 the AIEE committee on planning and co-ordination was given the special assignment of studying membership needs and desires for the intended purpose of guiding and stimulating the development of AIEE activities and services, the better to serve the Institute's rapidly growing diverse membership. In September 1945 two subcommittees of the committee on planning and co-ordination—one on technical activities and one on professional activities—were appointed by President William E. Wickenden (F '39).

The subcommittees were to study problems of growing urgency concerning the Institute's relation to the engineering profession as a whole and to the highly specialized organization and trends within its own field. At that time the subcommittees requested that members of the Institute submit comment, suggestions, and criticism as to what was lacking or needed to be changed in the way of services which should be available to members. Throughout the year opinions also were solicited at Section and District meetings and at the summer meeting.

From these investigations and the opinions so gathered, the subcommittees have fashioned several definite proposals, some of which have become Institute policy and others of which are under consideration.

To give an over-all picture of what has been done and the trend which its proposals are taking, the planning and co-ordinating committee submitted an outline of its activities at the close of the administrative year. This report is published in

New York, N. Y. (*continued*)

Test procedure program. *D.* Simplification and integration of devices.

6. General Discussion

2:30 p.m. Conference on Testing Telephone Receivers and Transmitters

This conference will be divided into three parts, as follows: 1. General introduction. 2. Brief talks by representatives of the industrial and research laboratories, including factory inspection and design. 3. Discussion from the floor.

Friday, January 31

9:30 a.m. Symposium on Lightning

47-97. Field Investigation of Lightning Surges at Substations. **I. W. Gross**, American Gas and Electric Service Corporation; **G. D. McCann**, California Institute of Technology

47-98. Photographic Study of Lightning. **J. H. Hagenguth**, General Electric Company

47-99. Field Research on Lightning Arrester Discharges. **G. D. McCann**, California Institute of Technology; **Edward Beck**, Westinghouse Electric Corporation

47-49. Burning of Wood Structures by Leakage Currents. **P. M. Ross**, Ohio Brass Company

9:30 a.m. Electric Machinery

47-3. Equivalent Circuit of the Primitive Rotating Machine With Asymmetrical Stator and Rotor. **Gabriel Kron**, General Electric Company

47-94. Accuracy of Temperature Measurement, on Coil Surfaces. **H. Martin Beede, B. M. Cain** General Electric Company

47–100. The Magnetomotive Force of 2-Layer Windings. **J. M. Stein**, Westinghouse Electric Corporation.

47-95. Liquid Cooling of A-C Turbine Generators! **C. J. Fechheimer**, consulting engineer

9:30 a.m. Symposium on Grounding of Portable Electric Equipment

The enormous increase in the use of portable electric tools and other equipment in manufacturing establishments makes it highly important that engineers concerned with the development, use, and maintenance of such equipment be well informed as to the need for safeguarding and methods of accomplishing it.

Report on Grounding of Portable Equipment· Committee on Article 250, Grounding, of the electrical committee, National Fire Protection Association

CP.** Discussion of the report to be presented by producers, installers, and users of connecting cord and plug equipment involved in such grounding

2:00 p.m. Power Transmission

47-89-ACO.* Meteorological Engineering for the Electrical Utilities. **H. A. Downs**, United States Department of Commerce

47-90. The Transient-Energy Method of Calculating Stability. **P. C. Magnusson**, Oregon State College

47-91. Internal Corona Discharges in Insulated Cables. **E. W. Greenfield**, Anaconda Wire and Cable Company

47-92. Radio-Noise Influence of 230-Kv Lines **H. L. Rorden**, Bonneville Power Administration

2:00 p.m. Industrial Instrumentation and Control

47-47. Radar Technique in Industrial Control **W. D. Cockrell**, General Electric Company

47-46-ACO.* Use of Electric Gauges in Quality Control. **Joseph Manuele**, Westinghouse Electric Corporation

CP.** The Influence of Electronics on Industrial Instrumentation. **H. D. Middel**, General Electric Company

CP.** Notes on Circuit Breaker Protection for Industrial Equipment. **R. R. McGee**, The Trumbull Electric Manufacturing Company

47-48. A Balanced Amplifier Using Biased Saturable Core Reactors. **H. S. Kirschbaum**, Ohio State University; **E. L. Harder**, Westinghouse Electric Corporation

2:00 p.m. Electric Machinery

47-93. New NEMA Fractional-Horsepower Motor Standards: Their Effect on Refrigeration and Pumping Applications. **C. P. Potter**, Wagner Electric Corporation

47-101. The Equivalent Circuit of the Capacitor Motor. **S. S. L. Chang**, Robbins and Myers Inc.

47-102. A Design Method for Capacitor Motors. **T. C. Lloyd, S. S. L. Chang**, Robbins and Myers Inc.

47-96. The Multistage Rototrol. **M. M. Liwschitz**, Westinghouse Electric Corporation and Polytechnic Institute of Brooklyn

2:00 p.m. Communications Components and Techniques

47-76. The Stromberg-Carlson XY Dial Telephone System. **H. R. Reed**, Stromberg-Carlson Company

47-77. Gas Pressure for Telephone Cables. **R. C. Giese**, American Telephone and Telegraph Company

47-78. Frequency Shift Telegraphy—Radio and Wire Applications. **J. R. Davey, A. L. Matte**, Bell Telephone Laboratories, Inc.

47-79. Some Modern Techniques in Ocean Cable Telegraphy. **C. H. Cramer**, Western Union Telegraph Company

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*ACO: Advance copies only available; not intended for publication in *Transactions*.

**CP: Conference paper; no advance copies are available; not intended for publication in *Transactions*.

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detail in the following paragraphs in the hope that still more comment and suggestions will be stimulated.

TECHNICAL ACTIVITIES

Review of Technical Functioning of Other Societies. The method of operation of some 30 national engineering societies was reviewed in detail by the various technical committee chairmen. Their comments and reports were analyzed and presented at the March 15, 1946, meeting of the technical program committee. This material was considered as background for further discussion of the organization of the technical activities of AIEE. The original reports have been turned over to G. A. Stetson, chairman of the committee on information of the Engineers Council for Professional Development, for use in its study of societies being made for Engineers Joint Council.

Midwest Meeting. The subcommittee, acting at the behest of the technical program committee, recommended that section 27 of the bylaws be changed to add an October meeting to the three national meetings now held. This meeting, to be known as the Midwest meeting, was recommended to provide an outlet for more technical papers and to start the technical activities of the Institute earlier in the administrative year. This was approved by the board of directors, and the first Midwest national meeting is expected to be held in the fall of 1947. [Editor's Note: at the Congress Hotel, Chicago, Ill., November 3–7, 1947.]

Winter Meeting in New York to Be Held in Hotel. The subcommittee, with the support of the technical program committee has recommended to the expiring winter meeting committee that it transmit ticket to its successors an instruction that an effort should be made to hold the winter meetings in a hotel rather than in the Engineering Societies' Building. The winter meeting committee has made this recommendation to the board of directors, and the board has appoved it. [Editor's Note: the 1947 winter meeting will be held as usual at the Engineering Societies' Building, as no New York hotel of adequate facility was available at the late date of the decision.]

Exhibits in Conjunction With Convention or District Meetings. Pursuant to a motion of the technical program committee that the Institute actively take under advisement the matter of sponsoring exhibits in connection with conventions, the subcommittee recommended to the winter convention committee that section 29 of the bylaws be revised to include rather than exclude the possibility of exhibits of commercial products. The winter meeting committee has made this recommendation to the board of directors, and the board has indicated that there is no objection to an exhibiting agency's conducting an exhibit concurrently with meetings.

District Meetings on Specific Subjects. At the winter convention conference Professor H. M. Turner (F '44) spoke on the advisability of holding technical conferences on specific subjects at specific locations, an idea that has received support from many sources. The subcommittee has recommended to the technical program committee that beginning immediately effort should be made to present national programs on specific subjects at District meetings held where some particular theme might be of regional importance. The technical program committee in endorsing the idea has recommended to the technical committees that such sessions be planned as soon as possible. The secretary of the technical program committee has been instructed to co-ordinate this activity with each District planning to sponsor a meeting during the next administrative year.

The board of directors adopted the following resolution at its June 27, 1945, meeting in Detroit:

Resolved, that the attention of the Districts be called to the merits of building the program of a District meeting around a dominant theme based on a subject of timely interest and particularly suitable to the location in which the meeting is to be held, that when this type of program is contemplated, the committee in charge of a District meeting should at the earliest opportunity notify the secretary of the technical program committee in order to take advantage of the assistance which is available to them in the appropriate technical committee or committees, the technical program committee, and the headquarters staff, and that such an occasion well might afford a favorable opportunity for a meeting of the technical committee or committees. It is to be understood that a District meeting is the responsibility of the District concerned and hence that the initiative in planning and arranging for a meeting of the type suggested lies with the District executive committee.

Closer Co-operation With Committees of Other Organizations. In discussion of plan *A* (the Coover proposal for a combined electrical engineering society) at the technical program committee meeting on March 15, 1946, it was agreed generally that, regardless of what plans might develop, closer co-operation with other national electrical engineering societies on technical activities should be initiated by the Institute. Accordingly, a motion was passed that the secretary write to the chairmen of all technical committees calling attention to section 86 of the bylaws which encourages such co-operation, urging each chairman to review all contacts and explore the possibility of establishing others. Since that meeting several possibilities of joint meetings with outside technical committees have come up for consideration.

Problems of Papers Arising in Joint Meetings With Other Societies. In discussing greater co-operative technical efforts with other societies the matter came up of traditional prohibition of joint publication of papers with other societies. The technical program committee voted to urge that consideration be given to joint publication of papers of mutual interest with other engineering bodies. Since the ban seems to be in the sentence: "No manuscript, any appreciable portion of which has been published elsewhere, is acceptable," which is contained in the publications committee portion of the pamphlet, "Information for Authors," the subcommittee has entered into discussion with the publication committee concerning this limitation.

General Publication Policy. Incidental to its accumulation of suggestions on the technical organization of the Institute, the subcommittee has received scores of suggestions involving the general publication policy of the Institute. These suggestions have been collected and summarized, and copies were distributed to the publication committee, the professional and technical activities subcommittees, and the technical program committee.

At the May 14, 1946, meeting of the board of directors at Asheville, Secretary H. H. Henline (F '43) submitted proposals originating with the headquarters staff for revisions of the publication policy which were approved in principle, and Secretary Henline was requested to submit the proposals and the board's action to the publication committee. At the August 2, 1946, meeting of the board of directors in New York the publication committee requested authorization for certain stated significant changes in publication policy to cover the proposals. The board of directors approved the general approach to the problem of separating the publication of *Electrical Engineering* from the publication of technical papers; these papers to be presented to the membership as *Proceedings* of the AIEE. [Editor's Note: Detailed plans for enhancing the publication program were approved and financed by the board of directors at its October 23, 1946, meeting, and the program becomes effective with the January 1947 issue of *Electrical Engineering* (*EE, Dec '46, pp 576–8.*)]

Steering Committee of Technical Program Committee. Much of the subcommittee's time over the past year has been taken up with discussion of proper grouping, scopes, and responsibilities of the technical committees. After hearing Subcommittee Chairman M. D. Hooven's (F '44) informal report on the subject, the board of directors at its Asheville meeting on May 14, 1946, adopted the following resolution:

Resolved, that it is the sense of the board of directors that the technical activities subcommittee of the committee on planning and co-ordination should be guided by the following principles: (1) that such additional technical committees should be organized as may be needed to cover the important items of electrical technology; (2) that these technical committees should be grouped in appropriate divisions or groups with a steering committee for each group fairly compact in numbers and reasonably concentrated geographically to promote effective action; (3) that the members of the steering committees be appointed by the president, and the members of the technical committees be appointed by their respective steering committees, all to serve for one year; (4) that each year the group steering committees, in addition to appointing their several technical committees, make recommendations to the president through the secretary on the membership and organization of their respective successor committees, including at least two alternates for each chairmanship; (5) that in such recommendations the steering committee provide for a turnover of at least 25 per cent of the steering committee personnel each year. Further, that it is the intent of this board that the responsible committees should proceed with such changes as they may determine to be necessary and proper to effectuate these principles unless the proposed changes are at variance with either the constitution or the bylaws, in which event they shall be referred back to this board for further consideration.

Reports on Technical Activities Subcommittee Projects. Chairman Hooven presented verbal progress reports on the work of his subcommittee at the Southern District meeting at Asheville, May 14, 1946, the New York Section meeting on April 25, 1946, and the Detroit meeting of officers, delegates, and members, June 25, 1946.

PROFESSIONAL ACTIVITIES

Status of Special Committee on Registration of Engineers Changed. A recommendation to replace the present special committee by a standing committee was approved by the committee on planning and co-ordination and by the executive committee on December 11, 1945. The subcommittee, at the request of the board of directors, prepared a draft of the scope and duties of the proposed standing committee for incorporation in the bylaws. This draft was approved by the committee on planning and co-ordination and by the board of directors at its January 24, 1946, meeting. The new bylaw has been adopted and a standing committee appointed.

Recommendation to Approve and Aid Formation of Joint Student Branches. This recommendation likewise was approved by the committee on planning and co-ordination and by the executive committee. The president requested the committee on Student Branches to work with other societies in developing a specific plan of co-operation. A subcommittee of the committee on Student Branches is actively at work on this project.

Relieving the President of Some Duties, or More Effective Use of President's Time and Energy. Various means of relieving the president of some of his routine duties were discussed and analyzed throughout the year by the subcommittee, the main committee, and the board of directors. Finally, in accordance with the recommendation of the committee on planning and co-ordination the board of directors, at its meeting in Detroit, June 27, 1946, adopted the following resolution to supersede the one previously adopted on May 15, 1946, at the Asheville meeting:

Resolved, that it is the sense of the board of directors that:

(*a*). Attendance of the president at general meetings, District meetings, meetings of the Engineers' Joint Council, and other intersociety obligations, should take precedence over visits to Sections.

(*b*). The District vice-president shall be made fully responsible for the visits to local Sections. It shall be the duty of the District vice-president to receive all requests for Institute officer speakers and to co-ordinate these requests for all meetings in his area. If the District vice-president is not to make the visits personally, he may be free to arrange for other officers or members of the headquarters staff to be the official delegate when this appears to be the most effective method.

(*c*). At each summer meeting it shall be the duty of the secretary of the Institute to call a special meeting of holdover and incoming vice-presidents at which they shall be informed of their duties in co-ordinating the work in the Districts and instructing Sections on methods of obtaining officer speakers. [Editor's Note: This was initiated at Detroit in June 1946.]

(*d*). When the formal visits to Sections are made whether by the District vice-president or by some other officer, the same expense allowance will be paid by the Institute as if the visits all were made by the District vice-president.

(*e*). The committee on planning and co-ordination is requested to continue its study of the possibility of greater use of the District organizations.

Organization of the Engineering Profession. For purposes of discussion the subcommittee drew up four possible plans of engineering profession organization, and, after revision based on experience gained at the winter convention conference on January 23, 1946, published them in the April 1946 issue of *Electrical Engineering*. A questionnaire was developed to record the views of those who attend meetings at which the plans are discussed. Requests to have a subcommittee member or some other person attend meetings to discuss the work the subcommittee is doing have been met. Discussion sessions have been held at all intervening District and national meetings and at many Section meetings.

Activities of Special Interest to Young Engineers. The subcommittee is endeavoring to find out what the problems and needs of the younger engineer-employees are, and what can be done by the Institute to get and keep their interest.

Trial Use of Wire Sound Recorder and Reproducer. Chairman T. G. LeClair (F '40) of the subcommittee demonstrated the use of this equipment to the board of directors at its meeting in New York on August 2, 1946. Consideration is being given to the use of such equipment by the Institute.

ECPD Proposal for Uniform Grades of Membership. The subcommittee is studying the ECPD proposal for uniform grades of membership and has recommended changes to make the grades suitable for use by the AIEE.

Recommendation for President's Desk at Headquarters. The subcommittee endorsed the recommendation which has been sent to the headquarters committee, that a desk be provided at Institute headquarters for the use of the president.

Recommendation for Reports by Retiring Vice-President. In order that the incoming vice-president and secretary of a District receive the information necessary to carry on their duties, and to keep headquarters informed, it is recommended that each retiring vice-president present a report to the incoming vice-president by June 1st of the year in which he retires, with copies to the District secretary and the secretary of the Institute. This report should summarize the status of all activities in the District.

Future AIEE Meetings

Winter Meeting
New York, N. Y., January 27–31, 1947

North Eastern District Meeting
Worcester, Mass., April 23–25, 1947

Summer Meeting
Montreal, Quebec, Canada, June 9–13, 1947

Middle Eastern District Meeting
Dayton, Ohio, September 23–25, 1947

Midwest Meeting
Chicago, Ill., November 3–7, 1947

Technical Activity Innovations Reviewed by Chairman

The essential portions of an informal progress report of the technical activities subcommittee of the planning and co-ordination committee as presented to the board of directors at its October 23d meeting have been compiled for *Electrical Engineering* by M. D. Hooven (F '44), chairman of the subcommittee.

The technical activities of the Institute are in the process of rearrangement. The technical committees, in addition to carrying on their usual work in specific fields, are looking over their neighbors' fences, inspecting other back yards, and making certain that no segment of the electrical engineering field is left uncovered. The technical program committee, acting as a sort of congress of technical committee chairmen, has divided itself into working groups for the purpose of co-ordinating the activities of the technical committees in order to maintain a continuously developing technical program and arrange for the most effective presentation and publication of the papers, reports, and discussion arising from this program.

Last year, the technical activities subcommittee reviewed and digested the practices of 50 national engineering societies, the survey later being turned over to Engineers Joint Council; co-operated with the publication committee in its studies; suggested that a fourth national meeting be held in the autumn in the Midwest; suggested that exhibits be held concurrently with meetings; recommended that national programs on specific subjects be considered for District meetings; activated plans for closer co-operation on technical subjects with other national societies concerned with electrical engineering problems; and formulated general plans for grouping the technical activities of the Institute to insure full and efficient coverage of the electrical engineering field.

In considering this particular phase of the technical activities problem, the board of directors at the May 15, 1946, meeting at Asheville, adopted the following resolution:

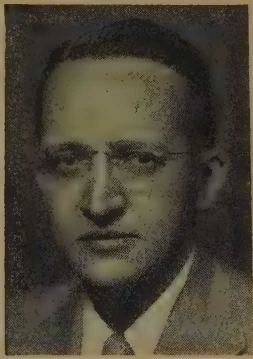
Resolved that it is the sense of the board of directors that the technical activities subcommittee of the committee on planning and co-ordination should be guided by the following principles: (1) that such additional technical committees should be organized as may be needed to cover the important items of electrical technology; (2) that these technical committees should be grouped in appropriate divisions or groups with a steering committee for each group fairly compact in numbers and reasonably concentrated geographically to promote effective action; (3) that the members of the steering committees be appointed by the president, and the members of the technical committees be appointed by their respective steering committees, all to serve for one year; (4) that each year the group steering committees, in addition to appointing their several technical committees, make recommendations to the president through the secretary on the membership and organization of their respective successor committees, including at least two alternates for each chairmanship; (5) that in such recommendations the steering committees provide for a turnover of at least 25 per cent of the steering committee personnel each year. Further, that it is the intent of this board that the responsible committee should proceed with such changes as they may determine to be necessary and proper to effectuate these principles, unless the proposed changes are at variance with either the constitution or the bylaws, in which event they shall be referred back to this board for further consideration.

Acting on the basis of this resolution, the technical program committee and the technical activities subcommittee considered various means for accomplishing the intent of the resolution. This resulted in the grouping of the chairmen of the technical committees considered as having closely related interests into four co-ordinating committees, namely: general applications, power, communications and science, and industry. Samuel G. Hibben (M '45) is chairman of the co-ordinating committee of the general applications group; M. J. Steinberg (M '32) of the power group, W. R. G. Baker (M '41) of the communications and science groups; and Herbert Speight (M '21) of the industry group.

W. R. G. Baker

M. J. Steinberg

S. G Hibben


M. D. Hooven

The chairmen of these four co-ordinating committees along with an alternate for each and such other members as were considered required became the technical program executive committee and also serve as the technical activities subcommittee of the committee on planning and co-ordination. The AIEE technical committees falling within each group follow:

Industry

Electric welding
Electrochemistry and electrometallurgy
Industrial control devices
Industrial power applications

Communications and Sciences

Basic sciences
Communication
Education
Electronics
Instruments and measurements
Nucleonics
Therapeutics

Power

Automatic Stations
Electric machinery
Power generation
Power transmission and distribution
Protective devices

General Applications

Air transportation
Domestic and commercial applications
Land transportation
Marine transportation
Production and application of light
Safety
Standards

This is considered a tentative basis of organization to be tried for possibly a year to observe its effectiveness before any attempt will be made to formalize it. It is realized that other arrangements of committee groups are possible. Those which were decided on after thorough discussion were considered to be most likely to promote the success of the plan. It is hoped that this plan will result in strengthening the technical structure of the Institute and in broadening its activities, so that any electrical engineer can find within the Institute provision for his participation in activities covering his particular field of interest.

The general committees with technical interests such as the Standards committee and the safety committee were invited to co-operate in this co-ordination of technical activities. Discussion indicated that the general applications group, the most loosely knit of the four groups, provided the best place at this time for these committees to contribute and to keep direct liaison with the general work of the technical committees. It is expected that the general applications group will contribute about 15 per cent of the technical activity of the Institute, as measured by sessions, conferences, and papers.

The power group, which includes some of the largest of the technical committees, is studying its own structure. While much discussion has taken place concerning the possibility of establishing a greater number of technical committees, it is too early yet to make any specific forecasts. It is expected that the power group of technical committees will encompass at least 35 per cent of the technical work of the Institute.

The communication and science group shows a disposition to tie together, for the present at least, several of the technical committees the scopes of which are interpreted to cut across the whole field of electrical engineering. Originally set up as two separate groups, the technical committees involved desired the present grouping to obtain a closer interrelation with one another. The group already has given birth to a new technical committee, the nucleonics committee, of which the proposed scope is:

> Treatment of all matters in which the dominant factor is nucleonics, particularly those dealing with the design, characteristics, or behavior of devices of a nucleonic nature or of systems associated with them. The treatment of complete equipments or systems may be considered within the scope of this committee, if they depend predominantly on the nucleonic principle for their operation. If the field of application of such equipments or systems falls also within the scopes of other technical committees, action with those committees shall be joint.

The work of the communications and science group will account for more than 30 per cent of the Institute's technical activity.

The industry group now is in the process of advancing a plan which probably will result in a total of seven or eight technical committees in a field where now only four exist. This is an obvious and laudable effort to expand in a technical area which requires more complete coverage. The expansion plan shortly will be submitted to the board. It is expected to result in a contribution by the industry group to technical activities which will be on the order of 20 per cent.

The grouping arrangement should result in many advantages, not the least of which is the possibility of a close tie-in with the new publication policy.

Co-operation with the Sections in technical matters is another subject which has engaged the attention of the subcommittee. Plans are being laid for exploratory conferences in this field, and suggestions are being solicited.

In conformity with the Asheville resolution, the technical administration for 1947 is already in the process of formation. Technical committee personnel in the past have been critical of the summer hiatus which necessarily occurs in technical work under the present method of appointment. At its March 7, 1947, meeting, the technical program committee proposes to assemble a full slate, with sufficient alternates of technical committee and administrative personnel for submission to the presidential nominee. This may be done under the present bylaws or presumably under new bylaws which the board may, by that time, have adopted.

Also in conformity with the Asheville resolution, the bylaws which concern the operation of the technical committees are being given close study in order to determine whether any of the changes being promulgated are at variance with them; if any are found to be so, they will be referred back to the board for further consideration.

The technical program committee as a whole, or its executive committee which is also the technical activities subcommittee of the planning and co-ordinating committee, meets the first Friday of every month. What it does on organizational lines cannot be considered to be exactly correct or exactly consistent by every individual. However, its present setup is designed to be extremely flexible, so that mistakes may be rectified easily and so that it may meet the problems of growth as they arise. It is not unreasonable to forecast that within a year there will be 30 rather than 20 technical committees and 6 rather than 4 co-ordinating groups. The present situation is fluid. Suggestions and comments are assured a welcome and a certainty of careful consideration.

What the New Publication Policy Means to Readers of Electrical Engineering

A new publication plan for *Electrical Engineering* and AIEE *Transactions* is now in effect as announced on pages 576–8 of *Electrical Engineering* for December 1946. Beginning with this January issue, *Electrical Engineering* will contain expanded general interest and news sections, and the *Transactions* section, which has been included since 1938 as an identical preprint from the annual *Transactions* volume, will be omitted.

Electrical Engineering in its enlarged scope is scheduled to carry to the entire membership not only a broadened coverage of general articles but also at least the essential substance of most AIEE technical papers according to their timeliness and general interest value. Thus the average member will receive material tailored to his needs and interest. An improved quality of paper now is being used, which represents a major advance in these times of critical shortages but is still short of the ultimate to be desired.

AIEE *Proceedings* is being established as a new series of publications which will supplement *Electrical Engineering* for the technical specialist who has particular need for the full formal text of technical papers and their related discussion. A single paper and its discussion will comprise an individual and separate *Proceedings* section. These sections will be available to Associates, Members, and Fellows on a selective basis designed to make available without charge to each individual those papers in which he is most intimately interested. Order forms announcing the availability of *Proceedings* sections will appear in *Electrical Engineering* from time to time; the first is scheduled for inclusion in the February issue.

AIEE *Transactions* will continue unchanged, and will be available on an advance-order basis for those who desire a permanent record of AIEE technical papers and discussions; price to members $4, to others $12, both plus foreign postage.

New Publication Policy Highlights

Electrical Engineering, issued monthly to all members, will contain:

1. **Articles of general interest.**
2. **All AIEE technical material in complete, condensed, or abstract form, depending upon scope and general interest of subject matter.**
3. **News of interest to AIEE members.**

AIEE Proceedings, furnished on special order, will contain full text of AIEE papers collated with their discussions.

AIEE Transactions, issued following the end of each calendar year on advance order, will contain in permanent bound form AIEE papers and discussions approved by the technical program committee and record material appropriately approved.

In the 1947 volume, discussion will be correlated physically with the paper to which it pertains. This volume will be issued as soon after the end of the calendar year as practicable.

Advance pamphlet copies of technical program papers will continue to be prepared by the photolithographic process or an appropriate equivalent in order to encourage and facilitate discussion at national and District meetings. Announcement of the availability of these pamphlets will be made in *Electrical Engineering* from time to time.

Second Lightning Reference Book Projected

As a service to AIEE members, there was published in 1937 by the Institute under the auspices of the power transmission and distribution committee a "Lightning Reference Book" which was compiled by the lightning and insulator subcommittee. It included a reproduction of some 200 technical papers on lightning which had been published up to 1935. These papers had been selected carefully by the committee to include the outstanding information on the lightning problem as it affected the electric industry.

Although a careful survey was made just prior to printing the book to determine the number of copies which would be required, it developed that, even though 900 copies actually were printed, the entire supply was exhausted at the time the book was published. This project, although a new one at the time of its inception, has proved of such interest to a considerable group in the Institute that the lightning and insulator subcommittee undertook about two years ago to survey current engineering literature with the idea of producing under the auspices of the Institute a second volume of the "Lightning Reference Book," covering the 10-year period from 1936 to 1945 inclusive. The work now is well under way, and more than three quarters of the technical papers which it is planned to include in the second volume already have been collected and reviewed. This second volume, as planned, will be much the same size as the first with approximately 1,500 pages and will include papers selected from those published between 1935 and 1946. It is not possible to include every paper published on the subject, but those of outstanding interest and significance are being selected by a picked group of specialists in the lightning field. It is planned also to include a bibliography of articles written in foreign languages, and a bibliography of American articles which, because of space limitations, it is necessary to omit from the book itself.

This work will be carried through to a conclusion if enough people are interested in obtaining a copy of the book to warrant the continued efforts of the lightning and insulator subcommittee and Institute headquarters in completing the work. Whatever the price eventually may be, it should be clearly understood that this volume is being produced on a strictly no-profit basis by the Institute. However, the work of compilation cannot be carried through if there is a sizable financial loss to the Institute, as it would be unfair to tax members not interested in this subject for the benefit of others. Progress on this project now has reached the stage where the work must be completed or abandoned.

ADVANCE ORDERS REQUIRED

As the cost of reproduction, paper, and other incidentals connected with the production of this book has increased considerably of late, the exact cost of the book delivered to members is not known definitely. Further, the cost will depend also on the number of copies which are printed. Therefore, to insure that every one who wants this book will be sure of obtaining a copy, and also as a means of determining whether enough people are interested in having a compilation of this kind, an advance copy commitment order appears on page 38 of the advertising section.

Persons interested in obtaining a copy of the "AIEE Lightning Reference Book, Volume II," should fill in this coupon at once and return it to AIEE headquarters. Immediate attention to this matter will be appreciated greatly by members of the lightning and insulator subcommittee who already have spent considerable time and effort on the project.

AIEE to Celebrate Edison Centennial in February

At the instigation of the Sections committee, the AIEE board of directors has authorized a project for suggesting to the 75 Sections and 27 Subsections of the Institute that local meetings be held on the evening of February 11, 1947, to commemorate the 100th anniversary of the birth of Thomas Alva Edison.

As Edison was a Charter Member of AIEE, when it was formed in 1884, the committee believes it fitting that the Sections take the lead in such arrangements. However, because of his fame and versatility in so many different fields, the plans call for extending invitations to other appropriate local sections of engineering societies and industry groups to join with the AIEE in paying tribute to the great man.

The suggestion to the Sections is that they hold dinner meetings to which all engineers would be invited. In this manner the expense of the entire meeting would be covered. Some Sections are planning a lecture meeting in a suitable hall which will be opened to the public, and in these cases the dinner feature will be omitted.

Through co-operation with the Thomas A. Edison Centennial Committee, the living Edison Pioneers and others close to Edison during his lifetime will be invited to participate in the individual meetings nearest their homes.

The programs of the centennial meetings are expected to vary depending on local conditions. The New York Section has reserved the Grand Ballroom of the Waldorf Astoria Hotel for the occasion. A special committee is being set up, composed of representatives of the jointly participating organizations. Close liaison will be maintained with the Thomas A. Edison Centennial Committee, which was established by the Edison Pioneers in 1944. It is hoped that the several celebrations can be integrated by means of a national radio program.

Fellowship Applicants Must File by February 15

Candidates for the Charles LeGeyt Fortescue Fellowships should file applications on the form provided by AIEE so that they reach the secretary of the fellowship committee by February 15. Awards will be made not later than April 1. Copies of the application forms are available at accredited colleges or at AIEE headquarters.

The Charles LeGeyt Fortescue Fellowship, sponsored by AIEE, was established in 1939 as a memorial to Charles Fortescue in recognition of his valuable contribution to the electric power industry. To this end the Westinghouse Electric Corporation, with which Doctor Fortescue was associated throughout his professional career, set up a trust fund of $25,000 to provide graduate fellowships in electrical engineering.

The successful candidates, selected by the AIEE committee which administers the fund, receive a minimum allowance of $500, and additional allowance may be granted at the discretion of the committee.

It is intended that candidates shall pursue their studies at accredited engineering schools and engage in research problems meeting the approval of the fellowship committee. To be eligible the student must have received a bachelor's degree from an accredited college by the time his work under the fellowship would begin, provided he does not hold or subsequently receive any other fellowship which carries a stipend greater than the tuition required by the institution at which the graduate work is to be undertaken.

Born in Canada in 1876, Doctor Fortescue was the first electrical engineer to be graduated from Queens University, Kingston, Ontario. He joined the Westinghouse company in East Pittsburgh, Pa., in 1898. A prolific inventer, he was the recipient of some 185 patents. He was awarded the honorary degree of doctor of laws by Queens University and the Elliott Cresson Gold Medal of the Franklin Institute, the latter for his system of symmetrical co-ordinates.

He also will be remembered for his rationalization of transformer design; for his studies of high-voltage measurements culminating in the adoption of the standard sphere spark gap; for his fundamental work on porcelain insulator surface shapes involving the "faradoid" principle; for his analysis of the fundamentals of transmission circuit stability; and for his theories of lightning behavior and the derived principles of lightning protection. He died in 1936.

Safety Committee Aids Student Programs

The committee on safety has prepared for the use of Student counselors and Student Branch chairmen a pamphlet on the subject of safety meetings.

With the collaboration of the committee on Student Branches copies are being sent to all such Institute representatives in the colleges as an aid in planning ways and means by which emphasis can be given to the subject of safety in Student Branch programs during the college year.

The pamphlet makes suggestions concerning types of meetings and topics that might be discussed by guest speakers or Student Members and includes a directory of principal organizations from which specific information may be obtained on request. A list of important references in the field of safety engineering and associated subjects of interest to the electrical engineer supplements the "Bibliography of Safety Literature" which was published by the committee on safety in 1942. Copies of the pamphlet may be obtained by addressing the chairman or secretary of the committee on safety.

The committee is ready to be of service to the Student Branches in connection with plans that may be formulated to carry forward the suggested program in an effective manner.

SECTION • • • • •

Section and Branch Take Joint Inspection Trip

The AIEE Dayton Section, the AIEE Student Branch of Ohio Northern University, and the Maumee Valley chapter of the Ohio Society of Professional Engineers recently participated in an inspection trip to the small motors division of the Westinghouse Electric Corporation, Lima.

Approximately 200 guests had dinner in the Westinghouse cafeteria at 6:15 and afterwards were joined by nearly 100 others. C. C. Shutt (M '43) manager of the division, spoke regarding the products manufactured by the small motors division and outlined the major inventions of George Westinghouse.

Mr. Shutt's talk was followed by a series of colored slides showing the importance of small motors in daily life. The narrative for the slides was supplied by C. G. Veinott (M '34).

At 8:00 p.m. groups of 15 were formed and were taken on a tour of the plant and laboratory. The inspection, which required two hours, was scheduled so that groups started at three different points at one-minute intervals to avoid congestion.

Mr. Veinott was in charge of the meeting, L. H. Fox (M '36) arranged for the inspection trip, and F. H. Gerlach (A '42) made the arrangements.

ABSTRACTS • • •

TECHNICAL PAPERS previewed in this section will be presented at the AIEE winter meeting, New York, N. Y., January 27–31, 1947, and will be distributed in advance pamphlet form as soon as they become available. Members may obtain copies by mail from the AIEE order department, 33 West 39th Street, New York 18, N. Y., at prices indicated with the abstract; or at five cents less per copy if purchased at AIEE headquarters or at the meeting registration desk. Prices for nonmembers will be twice those for members.

Mail orders will be filled
AS PAMPHLETS BECOME AVAILABLE

Air Transportation

47-14—An Integrated Control System for Aircraft D-C Generators; *A. T. McClinton (A '42). 15 cents.* This paper describes an electric system for d-c generators used on aircraft that allows physical integration of all control elements normally associated with the control of the generator. The proposed system differs from the present system used by the Army and Navy in that integration has been accomplished in addition to offering completely automatic control of the generating system without a sacrifice in system performance. Curves are presented showing the operating characteristics of the system. No attempt has been made to compare this system with present systems but rather to describe the individual control elements and to discuss their characteristics.

Automatic Stations

47-51—Automatic Control of Air Switches for Line Sectionalizing and Load Transfer; *F. W. Rich (A '41), M. S. Kirwen (A '42). 20 cents.* When a load center is provided with two sources of power supply, automatically controlled air-break switches provide a practical and economical means of maintaining service. The considerations involved in the design and application of automatic control of air switches are discussed in this paper with the thought that they might be used to guide designers and engineers who encounter similar problems. Three air-break switch control schemes are described, and the diagrams involved are shown. These control schemes were designed to provide automatic switching as follows:

1. Load transfer with synchronism check interlock, using d-c potential for operation and control.

2. Line sectionalizing and subsequent load transfer, using d-c potential for operation and control.

3. Load transfer, using a-c potential for operation and control.

The description outlines the operation of the various control devices for manual switching and for automatic switching which occurs during fault conditions.

47-54—Automatic Switching Schemes for Capacitors; *W. H. Cuttino (A'44). 15 cents.* The increased recognition of the benefits of capacitors as efficient generators of kilovars has resulted in rapid increases in the size and number of capacitor installations. When capacitor kilovars installed are greater than the light load kilovars, it often is desired to have the kilovars adjustable to avoid overvoltages or excessive leading kilovars at light load. The capacitor kilovars may be adjusted automatically by varying the voltage on the capacitor or by varying the amount of capacitor connected to the circuit. The amount of capacitors may be varied by automatically switching in equal or unequal steps in response to circuit conditions, or they may be switched by the same switching means controlling the load for some industrial plants. Capacitors also may be switched in combination with a voltage regulator to increase efficiently the effective range of the regulator. In some instances, it is desirable to have a kilovar generator which can furnish both leading and lagging kilovars. This may be accomplished by a combination of capacitor, reactor, and automatic tap changing transformer; by a combination of capacitor and synchronous condenser; or by a combination of directly connected capacitors and reactors. These various schemes are described and discussed.

47-55—The Economics of Using Capacitors in Amounts to Require Automatic Switching; *J. W. Butler (F'46). 20 cents.* At present price levels, capacitors generally can be justified in quantities considerably in excess of what electric systems can permit to be connected permanently. The average price of kilovars today as supplied by capacitors is one quarter of the price of 15 years ago, while other system equipment has increased in price 25 to 30 per cent during the same period. It is believed that, if the economics of capacitors are fully to be realized, switching procedures should be adopted more widely. In this analysis an over-all system investment point of view is taken, which speculates on what might be considered an economic operating power factor as a function of system and capacitor costs. A simplified method of determining the system energy loss savings through power-factor improvement is offered. A discussion on the practical minimum load power factor, system stability, light load voltage consideration, and so forth also is given.

Basic Sciences

47-34—The Physics of Electronic Semiconductors; *G. L. Pearson. 20 cents.* This paper outlines the band theory of solids and uses it to explain such properties of electronic semiconductors as.

1. The dependency of specific resistance on impurity content.
2. The negative temperature coefficient of resistance.
3. The sign of the Hall and thermoelectric effects.
4. The direction of rectification.

Measurements of specific resistance and Hall effect on typical semiconductors are described which enable one to calculate the density, mobility, and mean free path of the electronic carriers as a function of temperature and impurity.

47-87—Machine Computation of Power Network Performance; *L. A. Dunstan (A'40). 30 cents.* This paper discusses the computation of power network load flow studies as compared with the commonly accepted method of solving them with the network analyzer. The computation method is not impractically slow, if computations are performed by automatic computing machines of the variety ordinarily used for accounting purposes. A method of coding has been developed consisting of line numbers, bus numbers, loop numbers, track numbers, and track sequence numbers, so that reference to a single line diagram is not necessary to perform the computations. The machine sequences have been standardized. With punched-card accounting machines, the solution to a large network merely involves the processing of larger sets of cards than the solution to a small network. The machine computation method has been tested by recomputing a study originally performed on the network analyzer of the Bonneville Power Administration. The second approximation was of about the same accuracy as the network analyzer solution. Solution to this problem of 28 lines, 24 busses, and 5 loops required approximately 4,000 punched cards and 10 hours. This time compares favorably with the time required with an analyzer. The actual economic comparison between the two will depend upon intangibles such as the saving of drafting room work to prepare a computed study for reports, the greater future usefulness of punched card data and computations, the greater possible accuracy of the computed solution, and the possibility of combining accounting and engineering functions in the same equipment.

47-88—Effective Resistance of Isolated Nonmagnetic Rectangular Conductors; *H. B. Dwight (F'26). 15 cents.* The a-c resistance of isolated rectangular conductors has been the subject of a number of papers, and the determinations which have been published are sufficient, when brought together and correlated as in this paper, to give numerical values for nonmagnetic conductors for almost any such case encountered in practice. Tests from four different papers are shown, so as to make one family of curves. The results of the high-frequency formula of J. D. Cockcroft also are inserted, and information is provided as to when the frequency is too low for that formula to be used. A precise curve for convenient use of the high-frequency formula is given, as well as a discussion of skin effect and edge effect.

Communication

47-18—A 60-Cycle Hysteresis Loop Tracer for Small Samples of Low Permeability Material; *D. E. Wiegand (A'42), W. W. Hansen. 30 cents.* This apparatus was developed primarily for convenient and rapid measurement of the magnetic properties of magnetic recording wire and tape. The basic components are

1. A large (35 pound) exciting coil with a pickup coil at its center.
2. An amplifier-integrator.
3. A cathode-ray oscillograph.

Accuracy of measurement, greater than usual for this general type of apparatus, is achieved through the use of a built-in calibrating system and a compensated integrating network. In addition to its primary function, the calibrating system provides a definite means of adjusting phase angles. The integrating network provides a much higher output voltage than the simple series resistance-capacitance circuit and makes practicable operation at the power line frequency. Practically unlimited power available at this frequency makes possible the use of an open exciting coil of sufficient size to eliminate end effect errors and to allow operation at intense fields without overheating.

47-72—Television Equipment for Broadcast Stations; *W. L. Lawrence (A'30). 25 cents.* This paper describes a complete line of equipment for television broadcasting stations from camera to antenna. The equipment is classified into two major groups: studio equipment in which the signal currents are of video frequencies; and transmitting equipment, in which the signal currents are high frequency carriers modulated with appropriate visual and aural signals. The various units of equipment in each classification are described and illustrated, and their functional relation to the system as a whole is set forth. Advantages of product design equipment in attaining the high standard of operation required for commercial television broadcasting are noted. The complete line of equipment described is believed to afford a sound technical foundation for the establishment of a nation-wide commercial television service.

47-73—Postwar Television Receiver Design; *D. W. Pugsley (A'36). 15 cents.* The new postwar television receivers include many new design features and characteristics which result in an infinitely superior product to the consumer, not only from the standpoint of performance, utility, and reliability, but also from the standpoint of minimum obsolescence. It is the purpose of this paper to discuss some of these new design features which a progressive manufacturer certainly will include in his product to assure maximum customer satisfaction.

47-74—Television Network Facilities; *L. G. Abraham (M '39), H. I. Romnes (A '41). 15 cents.* This paper describes television network facilities which are needed to connect studios and other pickup points to transmitters in the same and in distant cities and discusses their transmission characteristics. Short haul television circuits may be by microwave radio or over wire circuits. Long haul television connections may be by radio relay or over coaxial systems of the type originally developed for carrier telephone circuits. Transmission requirements include adequate frequency band, accurate gain and phase equalization, and freedom from interference due to excessive noise, cross talk, or modulation. Radio and wire systems are under development to provide extensive, high quality television networks.

47-76—The Stromberg-Carlson XY Dial Telephone System; *H. R. Reed (M '34). 20 cents.* This paper describes a flat type of step-by-step switch and its associated equipment which recently has been introduced in this country for dial telephone switching systems.

47-77—Gas Pressure for Telephone Cables; *R. C. Giese (M '32). 25 cents.* This paper discusses the theory underlying the use of continuous gas pressure in telephone cables and covers the present status of its application. The primary function of gas in cables is to protect against interruption of service, by preventing entrance of moisture into the cable. The flow of gas in telephone cables is considered, taking into account the effects of compression, density, and velocity. The influence of changes in temperature, barometric pressure, and altitude are considered insofar as they affect cable pressures and the readings of instruments. Layout considerations; maintenance operations covering the detection, location, and clearance of leaks; and cable charging are discussed. Reduction of service troubles resulting from the placing of cables under pressure are summarized.

47-78—Frequency Shift Telegraphy—Radio and Wire Applications; *J. R. Davey, A. L. Mattee (M '36). 30 cents.* Frequency shift telegraphy is described and compared with amplitude modulation telegraphy under various conditions found in radio and wire transmission. Experimental data are given to demonstrate the influence of various design factors on the over-all performance under these conditions. It is shown that the most outstanding characteristic of the frequency shift method is its ability to accept large and rapid changes in signal amplitude. Frequency shift telegraphy thus proves to be of great advantage for use in the high-frequency radio range. Frequency shift telegraphy also shows an advantage over amplitude modulation telegraphy with respect to noise. For applications where the level variations are small or slow, the advantage of the frequency shift method over amplitude modulation is relatively small.

47-79—Some Modern Techniques in Ocean Cable Telegraphy; *C. H. Cramer (M '34). 25 cents.* Modernization of the nonloaded submarine telegraph cable facilities of the American trans-Atlantic cable systems in recent years has included conversion from cable code recorder operation to 5-unit code printer operation. The printer system is similar to the land-line multiplex printer system, providing the same types of message facilities including subchannels for direct customer-to-customer circuits. Conversion to printer operation became practicable chiefly because of substantial improvements in signal transmission obtained by:

1. Introduction of vacuum-tube amplifiers and improved signal-shaping networks replacing moving-coil magnifiers, and so forth.
2. High-accuracy duplex balances resulting principally from a new method of balance refinement involving frequency analysis of unbalances and resonant-type balancing networks.
3. Improvement of signal-to-interference ratios.

With these transmission improvements the net message capacity of the duplex-operated nonloaded cables of the Western Union system in printer operation averages more than 30 per cent above the previous recorder capacity.

47-80— A Carrier Telephone System for Rural Service; *J. M. Barstow (A '35). 30 cents.* A carrier telephone system suitable for supplying telephone service to rural customers over power lines is described together with a summary of power line treatment. This treatment consists of the application of coupling capacitors, terminating and coupling networks (at carrier frequencies), and the insertion at strategic points of carrier frequency chokes, but 60-cycle transmission is unaffected. The system provides a maximum of six 2-way channels over a power line and employs the double-sideband amplitude-modulation transmitted-carrier technique. Each channel is connected to a local telephone office by a voice frequency circuit and thus is an extension of the voice frequency circuit by carrier means over power wires. Terminal conversion equipments used both at the point nearest the central office and on the subscribers' premises are described functionally. The over-all operation of the system is almost identical with voice frequency party line operation.

47-81—Application of Rural Carrier Telephone System; *E. H. B. Bartelink (A '40), L. E. Cook (F '45), F. A. Cowan (F '45), G. R. Messmer (A '41). 20 cents.* This paper discusses the application of a carrier system developed primarily for providing rural telephone service over power distribution circuits in areas where this means of extending telephone service may be more attractive than other available methods. The modifications required in the power circuits to permit carrier frequency transmission, including the effect of these modifications on the operation of the power system, are described. Construction features also are discussed. The use of the rural carrier telephone system over open wire telephone pairs is discussed briefly.

47-82—Joint Use of Pole Lines for Rural Power and Telephone Services; *J. W. Campbell (M '39), L. W. Hill (M '31), L. M. Moore (F '45), H. J. Scholz (M '39). 30 cents.* Joint use of poles to supply power and telephone services has been employed since 1890. The rapid expansion of the use of higher distribution voltages and longer spans in rural areas for power distribution circuits in recent years required consideration of new methods of construction, electrical protection, and inductive co-ordination to facilitate joint use of poles under these conditions. This paper describes the methods developed and used in a number of installations to date in rural areas.

47-83—Rural Radiotelephone Experiment at Cheyenne Wells, Colo.; *J. H. Moore (A '19), P. K. Seyler, S. B. Wright (M '31). 15 cents.* The first rural party line telephone service by radio installations operating on the subscriber's premises was inaugurated August 20, 1946. This paper describes the equipment used, how it operates, and the results obtained during the preliminary testing and initial period of regular operation. Radio is one of several new methods which is being explored in its program for extension of telephone service in rural areas. It is expected that experience gained in this experiment will aid in developing a standard rural radiotelephone system.

47-86—Pulse Echo Measurements on Telephone and Television Facilities; *L. G. Abraham (M '39), A. W. Lebert, J B. Maggio, J. T. Schott. 20 cents.* Pulse echo measurements have been used on telephone and television facilities since 1940 to locate impedance irregularities and control quality in manufacture and installation. These sets send a pulse into a line and observe on an oscilloscope the echoes returned from irregularities. The shape and width of the pulse, the rate at which it is repeated, and the pulse magnitude are important in determining the accuracy of the results and the requirements of the measuring apparatus. The coaxial pulse echo set is used for factory and field testing of coaxial cables. The Lookator was developed for use on much narrower band systems such as spiral-four field cable and open wire lines.

Electric Machinery

47-16—A Study of the Relative Severity of Steep Front Waves and Chopped Waves on Transformers; *F. J. Vogel (M '41). 15 cents.* Reinforced turn insulation on the turns adjacent to the line coils of transformers has been used for many years in the belief that it would better enable transformers to withstand the transient voltages at the terminals. It was common belief that the turn insulation was the weakest link in the insulation structure of transformers, and that since the turn insulation was stressed by the rate of change of terminal voltage, it was immaterial whether the transient voltage was an increase or a decrease similar to the voltage collapse at flashover. The fact that turn insulation is not the weakest link, but that coil insulation is, requires means for determining the strength between coils. The coil stresses indicate that the coil strength is not determined by the rate of voltage change alone, but is greater when the voltage collapses on the chopped wave impulse test than for steep front waves.

Electric Machinery

47-93—New NEMA Fractional-Horsepower Motor Standards: Their Effect on Refrigeration and Pump Applications. *C. P. Potter (F'29). 15 cents.* This paper describes a logical method of rating fractional-horsepower motors on the basis of breakdown torque recently adopted by the motor and generator section of the National Electrical Manufacturers' Association. It also lists service factors for fractional-horsepower single-phase motors which were adopted at the same time, and explains the basis on which these service factors were chosen. Tables of locked rotor currents and code letters which have been NEMA Standards for some time also are included in the paper.

47-94—Accuracy of Temperature Measurements on Coil Surfaces; *H. M. Beede, B. M. Cain (M'46). 15 cents.* The purpose of this paper is to show quantitatively the relative accuracy of a number of methods commonly used for observing the temperature rise of coil surfaces. A total of 20 different combinations of temperature measuring devices and methods of applying them are compared from the standpoint of repetitive accuracy and the degree to which they indicate the true surface temperature. The greatest accuracy is obtained by using thermocouples made from wire approximately 10 mils in diameter and is improved further by enclosing the thermocouple junction in a metal pellet. Mercury in glass thermometers are the least accurate of the methods tested. The results of the tests clearly indicate that there is a wide range in the degree of accuracy among commonly accepted methods of observing the temperature of coil surfaces. The data obtained under laboratory conditions are confirmed by routine tests on induction motors.

47-95—Liquid Cooling of A-C Turbine Generators; *C. J. Fechheimer (F'14). 30 cents.* The advantages of liquid cooling over hydrogen cooling are that the machines can be made smaller; that nearly uniform temperatures are obtainable in the copper, for both rotor and stator; that rotor copper deformation is substantially eliminated; that the stator can be wound for higher voltages; and other gains. The difficulty hitherto has been the mechanical construction, especially of the rotor. Practical constructions for stator and rotor are shown. Other points covered are: relative heat absorption and heat transfer with several gaseous and liquid media; calculated temperature drops in a liquid-cooled rotor for 100,000 kva at 3,600 rpm; temperature distribution in, and deformation of, rotor windings, with gas and liquid cooling; starting a liquid-cooled generator; and comparison of machine sizes and construction. It is believed that it is at least as large a step from hydrogen to liquid cooling as it was from air to hydrogen cooling.

47-96—The Multistage Rototrol; *M. M. Liwschitz (M'39). 20 cents.* Until recently the only rotating amplifier used in practice was the amplidyne which is a modification of the Rosenberg machine. The amplidyne is a 2-stage amplifier of which both stages have the same number of poles. A new 2-stage amplifier has been described, which is independent of the Rosenberg machine, and which has the pole ratio 1 to 2. The aim of this paper is to show that, under certain conditions, a d-c machine may be adapted to operate with more than two stages having the pole ratios 1 to 2, 1 to 4, and so on. A 3-stage amplifier is described in detail, and two different coil arrangements for this amplifier are shown. Furthermore, the behavior of the 3-stage amplifier under transient conditions is investigated.

47-101—The Equivalent Circuit of the Capacitor Motor; *S. S. L. Chang; 30 cents.* Based on the cross-field theory of the capacitor motor, an equivalent circuit is derived, from which the following are obtained:

1. A method for performance calculation which involves no more than a few hours labor for the complete speed torque, efficiency, and power factor curves.

2. An accurate and comparatively simple expression of the maximum torque of a capacitor motor.

3. An approximate and very simple expression of the maximum torque for design estimations.

4. A condition for good efficiency and low noise which allows itself to be expressed very simply in terms of motor constants.

5. An expression for the pulsating torque at any speed.

6. A comparison of the equivalent circuits of the capacitor motor, the polyphase motor, and the plain single-phase motor, which not only is an interesting correlation of the fundamentals but also enables a designer to know what he can and ought to expect from his designs.

47-102—A Design Method for Capacitor Motors; *T. C. Lloyd (M'46), S. S. L. Chang. 30 cents.* This paper covers a design method for the permanent split capacitor motor, whereby the main winding can be determined to yield directly the desired maximum torque. Derivations based on the equivalent circuit show that the maximum torque of a capacitor motor is nearly independent of the auxiliary stator winding within the usual practicable limits of design. Starting torque calculations are presented in a different form, whereby useful curves can be plotted for the determination of the auxiliary winding needed to yield a required starting torque. As a further outgrowth of the equivalent circuit, the relationship of various parameters required for minimum torque pulsation and the most efficient design can be applied readily to the selection of the auxiliary winding. Designs for selected values of maximum and starting torques are illustrated by numerical examples, along with the effect of changing various factors.

47-100—The Magnetomotive Force of 2-Layer Windings; *J. M. Stein. 15 cents.* The analytical representation of magnetomotive force of 2-layer integral slot windings may be attained systematically by resolving the problem into four fundamental steps. For fractional slot windings the magnetomotive force is derived, without resorting to vector diagrams or charts, by inverse superposition applied to the recognized equivalence of a number of superimposed fractional slot windings to an integral slot winding.

Electric Welding

47-61—Voltage Changes Due to Resistance Welding Loads; *I. B. Johnson (M'45), H. A. Peterson (M'45), C. M. Rhoades, Jr. (A'44). 30 cents.* This paper presents useful quantitative data mostly in the form of generalized per unit curves showing the effect of single-phase resistance welding machine loads with and without phase control in producing voltage changes in the 3-phase system supplying power to the welders. These curves permit the ready determination of voltage changes to be expected at any location on a 3-phase system, for which the 3-phase short-circuit kilovolt-amperes and the X/R ratio of the system are known at the point in question. In addition the welder kilovolt-ampere and the full-wave power factor of the load must be known. Similarly, curves for frequency converted single-phase welder loads are shown. The quantitative data presented apply to a 3-phase 60-cycle source supplying power to a single-phase welder load through a 3-phase single-way phase-controlled frequency converter operated at frequencies of 20, $13^{11}/_{13}$, and $8^{4}/_{7}$ cycles per second.

47-62—The Voltage Drop in the Welder Throat Loaded With Ferromagnetic Materials; *G. M. Stein. 25 cents.* The voltage drop, induced in the throat of a projection welder by the introduction of ferromagnetic welding materials, has a considerable bearing on the required kilovolt-ampere rating of the welding transformer. For the determination of this voltage drop, the magnetic flux distribution in the throat, when loaded with two steel sheets, is calculated as a potential field. This analysis includes also the magnetic saturation of the iron, and is carried through for various dimensions of the throat and of the sheets, for different positions of the sheets in the throat, and for different welding currents. The calculation furnishes numerical values of the reactive and resistive voltage components which agree satisfactorily with test results.

47-63—Electrical Characteristics of Resistance Welding Tools; *E. M. Callender (A '35). 30 cents.* Methods of measurement and calculation of resistance welding tools, particularly for the large group of nonstandard type portable welding guns, are contained in this paper. Electrical characteristics have considerable bearing on

1. The kilovolt-amperes at an installation.
2. Required secondary voltage of the welding transformer.
3. Efficiency of the tool.

Time saving means, for either measurement or calculation, provide accuracies well within the average requirements of the engineer. The approximation calculation of inductance is semiempirical in nature to facilitate computation of tool or cable reactance and can be extended in principle to various types of welding equipment.

47-64—Functionalized Resistance Welding Control; *C. B. Stadum (A '43) W. E. Large, E. C. Hartwig. 15 cents.* In the past it has been necessary because of unco-ordinated circuit design to build synchronous-precision welding controls which were useful for only one application. By redesigning the welding control circuits and mechanically separating each basic electrical function, a versatile line of welding controls has been obtained. This paper describes some of the redesigned circuits in the new line of welding controls.

Electronics

47-68—The Shunt Tube Control of Thyratron Rectifiers; *J. A. Potter. 15 cents.* The "magnitude control" of thyratrons in regulated rectifiers is accomplished effectively by the use of a "shunt tube" bridged across the d-c output and resistance-coupled to the thyratron grids. The shunt tube grid operates from the output of a regulating feed-back amplifier to give precision voltage regulation and highly improved dynamic response to transients, as well as electronic ripple suppression. Extensive application of this recent development has been made in supplying plate power to video and d-c amplifiers for radars and computers. With the increased acceptance of thyratrons for power rectification in communication power supplies, an abundance of ingenious and valuable circuits has been devised. Among these are several regulating amplifiers employing shunt tube technique. Such circuits overcome an inherent sluggishness of thyratrons in regulating response to transients at no more than a moderate penalty to their basic economies.

47-69—Electronic Constant - Current Motor System; *O. W. Livingston (M '43). 20 cents.* This paper explains the operation of a new system of electronic control of a d-c motor which is capable not only of motoring but also of regenerating with rotation in either direction. Though inherently a constant torque system, it readily is converted to constant speed operation and has characteristics similar to a variable voltage drive. Further modifications show how the armature current may be held at low values during light load conditions and yet may be increased almost instantly to full load or even higher, if a sudden demand is experienced by the motor.

47-71—Arc-Back Testing of Graphite; *W. E. Pakala (M '45), C. J. Cucullu. 15 cents.* This paper describes a mercury vapor tube and associated circuits used to obtain the arc-back rate of various grades of graphite which might be applied in ignitrons and other types of electronic tubes. The method of test and results obtained are included. The tests indicate that the arc-back rate of a graphite anode can be reduced by degassing at 1,800 degrees centigrade and that this improvement is maintained at room temperature and at atmospheric pressure. It also is shown that anodes when not in operation get charged with arc-back causes of two classes.

1. Those that can be removed readily by heating.
2. Those that persist regardless of heating and apparently are removed by the arc-back itself.

47-84—A Magnetic Compass With Cathode-Ray Sensing Element; *W. H. Kliever, R. R. Syrdal. 20 cents.* This paper describes a remote indicating and controlling cathode-ray compass called "Cathotrol" in which the deflection of a vertical beam causes variation in the currents through four target plates, and these currents operating into a suitable resolver control a servo follower or a precession motor in a slave directional gyroscope. Resolvers use square potentiometers or 2-phase synchronous unit. A new tube was developed for this purpose having an over-all length of 7 inches and beam current up to one or two milliamperes at 300 volts. A null method of using the tube as a compass also is described. Optimum precession rates are determined for satisfactory operation with a slave gyroscope of an autopilot.

47-85—Electronic Null Detectors for Use With Impedance Bridges; *H. W. Lamson (M '28). 15 cents.* This paper gives a résumé of various modern types of null detectors employing electronic devices for balancing impedance bridges and other networks. The basic requirements for such null-detecting systems and the conditions for achieving a desired degree of sensitivity and selectivity are discussed. Two convenient polarized and directional null detectors are described.

Industrial Control Devices

47-17—Shading Coil Calculations for Single-Phase Magnets; *C. T. Evans (M '20). 15 cents.* A procedure is suggested by means of which the watt loss in a shading coil of a single-phase magnet may be calculated with reasonable accuracy, taking into account the flux distortion in the iron due to saturation. An experimental method is described by means of which the validity of this approximation is confirmed. This experimental method may be used for the study of the nonlinear micromicrofarad-flux relationship existing in magnets of this type, over a wide range of physical proportions and sizes, without building the actual magnets.

47-19—A Thrustor Lowering Control System for A-C Crane Hoists; *E. L. Schwarz-Kast (A '41). 20 cents.* The problem of lowering control of a-c crane hoists is becoming increasingly difficult because of an increase in maximum speed and a decrease in the creeping speed. On the one hand there is a trend toward an increase of the operating speed and, on the other hand, toward a lower creeping speed and better regulation. There are various systems in use, and in the last few years very remarkable improvements have been made. In spite of these achievements there is still a demand for a simple method which is safe, has low current consumption, a reasonable speed reduction and good regulation, accurate inching, and is inexpensive. Such a new system will be described and the test results given.

47-20—Dynamic Braking by Self-Excitation of Squirrel-Cage Motor; *A. Srinivasan, M. A. Thomas (M '39). 15 cents.* With high production machines requiring rapid duty cycling and accurate positioning, it is important that the period of idle running of a machine be reduced to a minimum. At least four methods for applying a braking torque to a squirrel-cage induction motor and its load are known for rapidly bringing the system to a stop. This paper deals with the dynamic braking produced by a system of static capacitors and resistors connected across the terminals of the motor, taking into account the varying frequency as the motor slows down. It compares the advantages and disadvantages of this method of braking control with those of the others in use for squirrel-cage motors. It presents a simple graphical solution to calculate the torque-speed characteristic of a given motor, capacitor, and resistor combination with a minimum of experimental data on the motor. A method to obtain the speed–time relation also is given.

47-21—Dynamic Braking of a Single D-C Series Motor; *J. D. Leitch (M '42). 15 cents.* In many applications of d-c series wound motors it is necessary to provide dynamic braking in the event of power failure. This is accomplished by four spring-closing contactors, only two of which must close on power failure to provide the appropriate dynamic braking circuit according to the direction of rotation of the motor. The present method of assuring the closure of the appropriate pair of spring closers is essentially mechanical. A scheme of control which is entirely electrical is proposed. Each of the four spring closers is equipped with two coils, one connected across the motor armature and the other across the line. In one direction of motion the ampere turns of the coils are additive for one pair of spring closers and in opposition for the other pair. On power failure the contactors in which the coils are bucking will open magnetically to close their contacts, while the other pair will have their contacts held open by the armature voltage. The paper also discusses various methods of obtaining graduated braking automatically.

47-47—Radar Technique in an Industrial Control; *W. D. Cockrell* (*M '43*). *15 cents.* Radar, loran, and similar developments within the past few years have caused an advance in communication electronic engineering into a much broader field than the fundamental one of "transmitting intelligence over a distance." Many new circuits have been developed which are not concerned directly with amplification or wave radiation. These should find increasing use in the field of industrial electronics as well. In return the industrial electronic engineer can contribute his part to the development of these mutually desirable circuits. A typical industrial circuit—a photoelectric side register control—is described to illustrate this fact and the desirability for close understanding and cooperation between the industrial and communication engineer for best circuit development."

47-48—A Balanced Amplifier Using Biased Saturable Core Reactors; *H. S. Kirschbaum* (*A '43*), *E. L. Harder* (*M '41*). *25 cents.* A balanced amplifier is described using saturable core reactors with bias windings. This is a true d-c amplifier with complete conductive isolation of input and output circuits and capable of reliable operation with inputs down to 0 to 0.0004 watt and amplifications up to 200 per stage. The life is unlimited, as there are no vacuum tubes. Though developed as a shockproof amplifier for certain regulating systems, it is believed to have a wide variety of other uses. An analytic method is derived for determining the amplification and time delay in a push-pull static amplifier. Formulas are given which will yield directly these quantities in terms of characteristics of the saturable reactor, and comparison is made with experimental data taken on an amplifier of the type described. Consideration is given to feedback, both positive and negative.

Industrial Power Applications

47-28—An Analysis of Motor Selection for Brass-Slab Rolling-Mill Service; *L. H. Berkley. 20 cents.* This paper deals with problems and calculations encountered in selecting a motor drive for a slab-rolling mill. The problem is presented to the reader and the possible solutions discussed. After all but two possibilities (a low-slip and a high-slip induction motor) are eliminated, detailed but simple calculations are made to make the final selection. The effective inertia of the system is obtained experimentally, and by calculation, the power generated and the energy contributed by the flywheel are calculated, and the rms horsepower required of the driving motor is obtained. It is expected that the calculations used and explained in this paper will be useful to motor-application engineers on many problems.

47-29—An Extension of Impact Speed Drop Analysis; *F. E. Crever* (*M '45*). *25 cents.* The formulas for the transient speed change on a d-c motor resulting from impact loading, as encountered in steel mills, have been available in a form which does not lend itself to quick calculation nor give a clear picture of the effect of varying certain factors. The formulas therefore have been put in a form dependent upon dimensionless ratios, and calculations have been put in chart form to allow quick determination of the transient speed change due to impact loading; also, the charts clearly show the effect of variation of the determining factors.

47-30—Cathodic Protection of Steel Water Tanks Using Aluminum Anodes; *L. P. Sudrabin, R. B. Mears. 30 cents.* Since 1935, cathodic protection has been applied to over 4,000 industrial and municipal water tanks in the United States and Canada. Aluminum alloy anodes have been used for approximately 1,000 of these installations. From fundamental considerations it would be expected that the loss in weight per ampere hour of current passed from aluminum anodes would be less than 1/3 the weight loss from steel anodes. This expectation is confirmed in service. In addition, it has been found that aluminum anodes develop a more uniform attack than do anodes of steel or stainless steel. The corrosion products from aluminum anodes are white or colorless and adhere to the anodes. In the case of anodes of many other materials, the corrosion products are strongly colored and fall off the anodes, thus discoloring or otherwise contaminating the water. Anodes of several aluminum-base alloys all have proved satisfactory in field installations. However, anodes of the aluminum-copper alloys (such as 17*S-T* or 24*S-T*) appear to be superior to anodes of unalloyed aluminum (2*S*) or to aluminum-zinc alloy anodes in installations where current is supplied from an external source.

47-31—A Selective Grounding System; *E. Herzog* (*M '29*). *15 cents.* A grounding system utilizing ground neutralizer coils and by-pass resistors is being installed on an industrial system at the unusually low voltage of 6,600 volts. Manual selection between neutralizer coil and resistor grounding is provided to avoid interruptions due to fault clearing except under controlled conditions. The coil is provided with remote control for retuning, and multiple coils are provided to decrease further the need for retuning. Where process conditions require elimination of even short interruptions, except on prearranged schedule, manual control of the by-pass resistor has distinct advantages. Arcing fault troubles made the continued use of the ungrounded system impossible as the cable system expanded, but operating conditions made solid or resistance grounding inadvisable because of the danger of unscheduled interruptions. It is expected that the neutralizer coil will reduce fault current to a point where continuous operation with a ground fault will be possible; this is based on experience with the ungrounded system. The by-pass resistor will permit rapid selective clearing of the ground fault, compared with the trial and error method during ungrounded operation. This is accomplished with much less burning than occurs on a solidly grounded system. Technical features as applied to the particular system are discussed in detail.

47-32-ACO—Electric Drives for Textile Finishing Ranges; *R. B. Moore* (*A '45*), *H. C. Uhl* (*M '40*). *30 cents.* The continuous finishing of textiles with machines operated in tandem, or "in range," requires carefully co-ordinated adjustable-speed machine drives. Electric drives, as compared with mechanical drives, generally offer several advantages and are used predominantly on modern range installations. Of the electric systems, d-c drives are most generally suitable and most widely used, although a-c drives are used advantageously under certain circumstances. There are several types of co-ordination control that may be used on range drives, each type having certain advantages and disadvantages, depending on the basic type of range drive used. This paper gives general information on textile ranges, basic requirements of range drives, basic considerations in selecting drive equipment, comparison of electric and mechanical drives, description of various types of electric drives and co-ordination control, and recommendations for selecting proper equipment for specific conditions.

47-33—Electrification of the Cotton Industry in the South; *S. A. Bobe* (*M '44*). *20 cents.* This paper outlines the application of electric equipment in the cotton industry. Electrification permitted cotton mills to locate at most advantageous points from standpoint of raw materials and labor. Present trend is to purchase rather than generate power. Distribution equipment in newer mills follows best practice as found in industry in general, including unit substations. A brief description of cotton processing with data on horsepowers and speeds required for principal drives is given. A more detailed description is given on a new sectional variable-voltage drive for sizing warp which uses a rotating regulator for tension control.

47-35-ACO—Electric Equipment for 2-for-1 Twister; *E. C. Gwaltney, H. J. Burnham.* *15 cents.* The paper describes the theory of operation and electrification of an upstroke continuous-filament synthetic-yarn twister which puts two turns of twist into the yarn for every revolution of the spindle. Individual 2-pole 3-phase induction motors drive the 72 spindles per machine at 12,000 rpm and are powered by a permanent field 3-kw 200-cycle 60-volt generator. Pushbutton starting and stopping of a 5-horsepower main driving motor belted to the generator controls the entire machine. Yarn take-up is driven by a 1/6 horsepower gear motor powered from the same high-frequency generator assuring constant relationship of spindle and take-up speeds and consequently constant twist. Advantages claimed are: reduction in power consumption, more even twist, easier stopping of individual spindles, simpler design, reduction in noise, and cleaner yarn.

Instruments and Measurements

47-22—Advancements in the Design of Long-Scale Indicating Instruments; *R. M. Rowell* (*A '42*), *N. P. Millar* (*A '44*). *20 cents.* Modern high accuracy switchboard instruments of a new long-scale type were developed and made available just prior to the war. These instruments were produced in large quantities for the United States Navy during wartime and have demonstrated their value. Combat use has been an excellent proving ground for these instruments and has at the same time indicated the direction of advancements in design for commercial applications now being made. The improved performance of the new designs has been obtained by more efficient use of new materials, including Alnice and sintered iron, by novel compensating schemes, and by unique design features. These advancements in design are described in detail, and the resulting performance characteristics of long-scale ammeters, voltmeters, wattmeters, power factor meters, and synchroscopes are outlined.

47-23—Measurement of High Q Cavities at 10,000 Megacycles; *R. W. Lange.* *20 cents.* Known methods of measuring Q in high Q resonant cavities, together with their accuracies and sources of error are discussed. For relatively low values of Q and of frequency, it is shown that band width methods are more accurate than decrement methods. For values of Q above 30,000 at frequencies above 3,000 megacycles the reverse is true. The significant feature of the present method, the wide range heterodyne decrement method, is that the accuracy is improved by observing the decay over a relatively long interval of time. An absolute accuracy of ±3 per cent and a relative accuracy of ±2 per cent are achieved. Design features and performance are discussed, and constructional details are presented.

47-24—A Polyphase Thermal Ampere Demand Meter; *A. J. Petzinger* (*M '44*). *20 cents.* Reduction of the initial and maintenance costs of the metering equipment required for the measurement of kilovolt-ampere demand has been an objective of the metering industry for many years. The development of a method of measuring polyphase ampere demand has made possible a simple and compact meter which registers kilowatt-hours and indicates maximum ampere demand. A good approximation of true kilovolt-ampere demand then is obtained by multiplying this maximum ampere demand by an assumed base voltage.

Land Transportation

47-36—A 3,000 Horsepower Diesel-Electric Locomotive for the Seaboard Air Line Railway; *D. R. Stamples, T. L. Weybrew, C. A. Atwell* (*M '43*). *15 cents.* The locomotive recently delivered to Seaboard Air Line Railway is the most powerful Diesel-selectric locomotive ever built in a single unit. Its features include articulated-type trucks with good tracking characteristics, low axle weight, and a sufficient number of motors for all types of service. Haulage stresses are not transmitted to and through cab structures. Electrical transmission includes lightweight high-capacity motors operating in one combination at all times. Engine load control system is simple and eliminates overloading. Locomotive auxiliaries are motor-driven with power taken from main generators. Locomotive power control is done with one handle and gives smooth gradual acceleration without jerks and interruptions.

47-37—Developments in Diesel-Electric Traction-Generator Excitation Control Systems; *C. A. Brancke* (*A '41*), *G. M. Adams* (*A '41*). *15 cents.* A recently developed amplidyne excitation system uses saturable core reactors and selenium rectifiers to obtain a definite generator field current limit and several different generator armature current limit settings. It is used in conjunction with a new power plant regulator which compensates for variations in temperature, altitude, fuel, and engine ability by regulating the excitation, and hence the loading, to maintain proper speed on all notches. The current limits protect the generator by reducing the possibility of overheating. It also limits the commutation duty for which the generator must be designed. Several different generator load current limit settings permit the operator always to obtain the desired tractive effort. The excitation is regulated as a function of generator output, thereby eliminating variations due to changes in voltage supply, machine temperature, or individual machine characteristics, and always producing the same results. Small lightweight devices can be used throughout because of the exceptionally low energy input required by the amplidyne exciter. Most of these devices used in the limit circuits have no moving parts, thus reducing the possibility of trouble.

47-38—Braking Resistors and Control for Diesel-Electric Locomotives; *E. F. Weiser.* *15 cents.* Dynamic braking has proved to be a very desirable feature on the new heavy Diesel-electric locomotives being placed in railway service. Savings in brake and wheel maintenance on rolling stock have resulted in an increasing number of installations. The fundamental scheme of dynamic brakes uses the traction motors as generators excited by the main propulsion generator. Power generated by the motors is dissipated in a braking resistor. This resistor and the required power and control switches are the only additional equipment required to accomplish dynamic braking. Addition of a resistor of sufficient capacity indicated the need of an entirely new and radical design to meet space and weight restrictions. A high-velocity air-blown resistor has been developed in which considerable attention was given the heat transfer and air flow, resulting in a compact lightweight design.

47-39—A Power Plant Regulating System for Diesel-Electric Locomotives; *C. B. Lewis* (*A '44*). *15 cents.* This paper describes a new power plant regulating system, which incorporates speed and load control, recognizes the ability of the engine, permits maximum utilization of the engine's power, and protects the engine from harmful overloads. The ability of the regulator to schedule permissible engine fuel as a function of engine speed allows it to be used with the latest type engines employing superchargers. The system permits remote and multiple-unit operation and provides a high degree of plant protection against damage because of failures.

47-40—Developments in Control Systems for Diesel-Electric Locomotives; *M. D. Henshaw.* *20 cents.* The field of application of single power plant per cab locomotives was broadened greatly in 1945 and 1946 by the arrival of new Diesel engines of 1,500- and 2,000-horsepower ratings, designed specifically for railway service. These higher ratings, together with improvements in the generator and motor elements of the electric transmission systems, demanded new standards of precision in the control system. This paper describes the new development in control circuits and apparatus made to answer those demands. Of chief interest is the excitation system using an amplidyne exciter in conjunction with a power plant regulator and saturable reactor limit controls. Included also is a high-capacity dynamic-braking system, a simple auxiliary power arrangement, the use of timed-frequency relays for transitions and overspeed control, a new water temperature control, and other innovations in apparatus, panels, and lighting.

47-41—Some Recent Developments in the Presidents' Conference Committee Car; *S. B. Copper.* *15 cents.* The PCC car was developed about ten years ago as a result of a co-operative research program by the major transit operating companies and manufacturers. This paper briefly reviews the history and experience with the car and outlines the recent changes and improvements. New performance curves are included.

47-42—Recent Developments in Track Brakes and Drum Brakes for Presidents' Conference Committee Cars; *S. J. Vouch. 15 cents.* Transit vehicles today must have superior accelerating and braking characteristics to keep their place in the present-day traffic stream on our city streets. The PCC car has kept pace with traffic demands through improvements in braking equipment which provide higher emergency braking rates with increased reliability. Magnetic track brake shoes provide separate friction surfaces with the rail supplementing adhesion between wheel and rail for stopping under adverse rail conditions.

47-43—Modern Car Equipment for New York City's Subway System; *B. F. Cordts. 15 cents.* This paper describes some of the outstanding features of the 400 new subway cars recently ordered for use on the Brooklyn, Manhattan Transit–Independent Division, and 100 cars for use on the Interborough Rapid Transit Division. Fluorescent lights, using 72-inch cold-cathode lamps and operating direct from the 600-volt d-c third rail will give these cars over 15 foot-candles on the reading plane. Better riding qualities are expected from several changes in truck design. Acceleration and decleration rates and their effect upon riding comfort, power, control, and scheduled speeds are discussed in detail. Noise reduction, being so desirable in subway structures, received careful consideration, and six specific improvements are described in the section on "Reduction of Noise." The last portion of the paper outlines many other items, contributing either to better operation or to increased passenger comfort.

47-53—Investigation of Silicone Insulation on High-Temperature Railway Motor; *George Grant, III (A'44), T. A. Kauppi (A'44), G. L. Moses (M'44). 20 cents.* Thermal aging and humidification tests are reported on a silicone-insulated railway motor. This included 1,675 hours at a temperature of 285 degrees centigrade with 46 cycles of severe humidification. Loss of initial moisture resistance was observed, but no operating failure occurred. No change occurred in the heat dissipating characteristics of the machine. Finally, the motor was dismantled and the insulation examined in detail. Thermal aging data are interpreted.

47-44—Special 10-Car Train for New York City Transit System; *J. J. Sinclair. 15 cents.* This paper deals with a general description of a proposed lightweight car constructed of low-alloy high-tensile steel, aluminum, stainless steel, or a combination thereof to embody various special features such as attractive appearance; reduction of noise; easy riding qualities; forced ventilation, including air filtering and sterilization; uniform heating; fluorescent lighting; electric door operators; motor alternators for lighting; sterilizing lamps; and sign lamps. Two types of lightweight trucks have been designed for these cars. Such trucks are to be equipped with resilient wheels, roller bearings, two 100-horsepower motors, one for each axle, with flexible right angle drive, hypoid gears, and drum brakes on each axle.

47-45—Can the Trolley Coach Compete Economically With the Gas or Diesel Bus When No Overhead Facilities Exist?; *J. H. Gauss. 15 cents.* For many years the trolley coach has been considered a vehicle to be used to modernize old street car lines. Much emphasis has been given to the fact that, because of the salvage value of existing overhead facilities and substation equipment, the trolley coach was the most economic vehicle. We have lost sight of the fact that the trolley coach is entirely capable of standing on its own, regardless of the existence of power facilities. This is substantiated by the fact that many trolley coach installations have included entirely new overhead and substation installations. Often the distribution system of a street car line was as obsolete as the cars at the time of modernization and needed replacement in its entirety. Further, on some properties, trolley coaches have replaced busses, resulting in a substantial increase in net revenue for the operator.

Metallic Rectifiers

47-25—Higher-Voltage Copper-Oxide Rectifiers; *I. R. Smith (A'43). 15 cents.* Copper-oxide metallic rectifier output voltage ratings per cell have been limited for many years to relatively low values. The progress of a development is described by which previous voltage ratings were doubled successfully.

47-26—Electrical Characteristics of the Junction in a Simplified Selenium Rectifier Cell; *S. J. Angello (A'42). 20 cents.* The selenium-cadmium contact is a simplified selenium rectifier cell and is studied with the purpose of understanding the physics of contact resistance asymmetry. A theory by W. Schottky which predicts the contact resistance at zero voltage and the course of this resistance with d-c reverse voltage is not adequate to account for the experimental data. An attempt has been made to extend the theory by assuming a fraction of the bromine ions in the selenium to be free. Agreement with experiment is obtained for low voltages at a high temperature, but for higher voltages at all the temperatures employed there is marked disagreement. The theory developed is sufficiently general to conclude that the contacts studied either have a polarizable layer less than 10^{-6} centimeter thick between the cadmium and selenium, or there is a mechanism of deactivation of bromine ions at higher voltages.

47-27—Automatically Controlled Copper-Oxide Rectifiers for Electroplating and Anodizing Applications; *J. J. Buckley (A'41). 15 cents.* This article treats of some of the underlying principles governing the rating of the copper-oxide cell. It goes on to describe the type of copper-oxide stack used in electroplating and anodizing applications, and also the 12-kw rectifier unit which is generally a component of automatically controlled installations. The desirability of having a varying alternating voltage applied to the unit, the magnitude automatically changing to counteract load resistance or a-c line fluctuations, is brought out; and the induction-type control used for this purpose is outlined. Circuits are presented for maintaining constant voltage, constant current, and so forth, and characteristics such as over-all efficiency and power factor are included.

Power Generation

47-56—Testing Governor Performance on Electric Power Systems With Improved Instruments; *J. E. Allen (M'39), W. B. Hess. 30 cents.* This paper describes improvements in instrumentation applicable to testing both steam and hydroelectric governors while regulating on system frequency. An important feature of the testing equipment is the recording in *X–Y* co-ordinates of frequency versus operating piston motion or frequency versus kilowatts output. The resulting card diagrams give important governor performance characteristics such as sensitivity, dead band, incremental speed droop, and incremental speed regulation. The usual strip chart records of frequency, operating piston, and kilowatts as a function of time are recorded simultaneously with the same instrument. The essential element is a new direct writing frequency recorder having fast pen speed, large pen arm force, and high sensitivity. Numerous records of actual governor tests are included to demonstrate the applications of the instruments and to illustrate the influence of friction and adjustments on over-all governor performance.

47-57—Automatic Control of Hydroelectric Generating Stations; *M. J. Brown (M'44), W. A. Derr (A'43). 30 cents.* This paper discusses hydroelectric station equipment, operating procedures, and the factors involved in applying automatic control. Hydraulic governors and the types of water wheels (impulse, reaction, fixed propeller, and adjustable propeller) are described from the electrical engineer's viewpoint. A typical automatic control diagram is shown for each of the two methods commonly employed for accelerating the generator and synchronizing it with the system. In one method, termed self-synchronizing, the machine circuit breaker is closed at less than synchronous speed, and the machine synchronizes after its field is applied. In the other method automatic speed matching and synchronizing equipment bring the machine on the line at correct voltage and phase angle. Considerations involved in applying supervisory control to automatic hydroelectric stations are presented.

47-58—Modern Bearing Practice for Vertical Water Wheel Generators; *C. M. Laffon* (*F'45*), *R. A. Baudry*. *20 cents*. In the United States approximately 80 billion kilowatt-hours of electric energy were produced in 1945 by hydroelectric power stations. This represents 35 per cent of the total electric energy produced by the electrical utilities industry in this country. The vertical type hydroelectric unit is the best suited to meet the wide range of speed which is required, and the use of this type of unit has become accepted practice. The need for units of greater capacity has necessitated a parallel increase in dimensions of guide and thrust bearings. This has required a further improvement in design and manufacturing procedure. The required information has been obtained from laboratory tests and field experience. A better understanding of the performance requirements of vertical water wheel generator thrust bearings has made possible the development of single, compact machines which are less costly to erect, easier to operate, and have increased performance reliability.

Power Transmission and Distribution

47-49—Burning of Wood Structures by Leakage Currents; *P. M. Ross* (*M'40*). *20 cents*. Wood pole or structure fires of leakage current origin have caused serious wood member damage and service interruption. These fires often occur at the end of prolonged dry periods. Operating experience indicates surface "tree" carbonization on crossarms, and "pocket" burning at the crossarm-pole junction to be the two general types of burn damage. "Pocket" burning on some properties has been responsible for the greater part of the cases that required wood member replacement. Shunting devices which by-pass leakage currents around dry, high resistance areas have proved successful in laboratory tests in eliminating "pocket" fires within the by-passed zone.

47-89—Meteorological Engineering for the Electrical Utilities; *H. A. Downs*. *15 cents*. Electrical utilities find advance weather information absolutely indispensable. Clouds, rain, freezing rain, snow, thunderstorms, gales, temperature, and humidity vitally affect the operation of an electric power system. As strong and comprehensive as these statements are, they do not seem to be an altogether adequate stimulus for a more effective understanding of the mutual problems of the electric power and meteorological professions. This paper broadly considers just what information and services are available from the Government weather man or from the private meteorologist, as adapted and interpreted from Government reports and forecasts.

47-90—The Transient-Energy Method of Calculating Stability; *P. C. Magnusson* (*M'46*). *30 cents*. The transient-energy method of calculating transient stability is applicable to systems of three (or more) synchronous machine in which the latter may be represented by constant-magnitude voltages behind fixed reactances, and in which losses and nonsynchronous loads may be assumed constant. The minimum energy required to displace the machine rotors from their steady-state after-transient relative positions to an unstable relative position is the allowable transient energy. It is compared with the initial transient energy, which is the sum of the potential and kinetic energies (calculated with the steady-state after-transient conditions as reference) which the rotors possess at the start of the transient.

47-91—Internal Corona Discharges in Insulated Cables; *E. W. Greenfield* (*M'37*). *30 cents*. The application of internal discharge (corona) detecting and measuring equipment to the evaluation of insulated cables is discussed and results obtained on type-*CB* conductor-shielded and standard type-*H* impregnated-paper constructions presented. The "internal corona detector" is described as a completely self-contained and portable unit. It incorporates a bridge-type circuit which suppresses the 60-cycle applied potential and its harmonics, permitting high amplification of the high-frequency harmonics produced by the internal discharge. The volume of discharge can be determined quantitatively by means of a calibrated vacuum-tube voltmeter, or visually by an oscillograph. The detector is applicable to all types of cable and may be adapted for use with other electric equipment. This is a very sensitive and valuable tool for the determination of insulation quality. Information obtained on volume and character of the internal discharges, together with supplementary data, disclose that in impregnated-paper constructions type *CB* has outstanding stability under severe conditions of stress and temperature.

47-92—Radio-Noise Influence of 230-Kv Lines; *H. L. Rorden* (*M'36*). *15 cents*. The difficulties of obtaining materials during recent years have made it necessary to economize in the design of new transmission facilities. Under war conditions the Bonneville Power Administration took such limited means as were possible to determine if economies could be effected in transmission line design without lowering the standard of service. One of the first departures from previous practice involved the use of wood poles for transmission of power at 230 kv. Design of the first line of this type on the Bonneville–Coulee system was based on previous practice of similar installations in other parts of the country. This 230-kv line is 185 miles long, contains H-frame structures with 22-foot conductor separation, 1.108-inch American cable steel reinforced conductor; uses 13 standard $5^{3}/_{4}$-inch suspension insulators; and is not protected with ground wires. It was built to relieve a serious bottleneck during the war emergency.

47-97—Field Investigation of Lightning Surges at Substations; *I. W. Gross* (*F'45*), *G. D. McCann* (*M'44*). *20 cents*. Results of a 7-year field investigation of lightning surge currents and voltages at 12-kv to 132-kv stations on a large power system are presented and discussed. The objects of the research were to determine the surge current and voltage characteristics of natural lightning as they exist under normal field conditions, and as they may affect the duty placed on electric apparatus and protective devices, such as the lightning arrester. Characteristics of surges such as magnitude, wave shape, duration, and frequency of occurrences are presented and correlated with previous similar data where such existed, and a comparison was possible. General conclusions are given on the practical significance of the results as applied to lightning protection.

47-98—Photographic Study of Lightning; *J. H. Hagenguth* (*M'44*). *25 cents*. The paper is a summary of a lightning investigation extending from 1935 to 1941 in Pittsfield, Mass., by means of cameras. The cameras are described briefly. This method of measurement does not yet permit determination of current amplitudes but yields statistical information on several important factors such as duration of discharges, multiplicity of current peaks in the discharges, frequency of occurrence of continuing discharges, and their duration. Interesting results were obtained concerning the stroke frequency and density in a region with an isokeraunic level of 25. A comparison is made between the results presented in the paper and those obtained by other investigators.

47-99—Field Research on Lightning Arrester Discharges; *G. D. McCann* (*M'44*), *Edward Beck* (*M'35*). *15 cents*. This paper gives a summary of the data obtained in an investigation extending over a period of seven years on the frequency, magnitude, and wave shape of the lightning currents discharged by arresters, both in substations and on distribution circuits. Nineteen substations were studied providing data on 133.5 single-phase arrester years of operation. Six distribution systems were studied covering 160 arrester years. Two hundred and twenty six records of single discharges of arresters in stations have been recorded comprising 294 individual components giving magnitude and wave shape data. Ninety distribution arrester records were obtained with 114 individual components. A statistical summary of the data is given in terms of percentage distribution curves on the frequency of arrester discharges, their crest magnitudes, polarity, wave fronts, times to half value, and duration.

Protective Devices

47-50—An Improved Automatic Circuit Recloser; *J. M. Wallace (A'41). 15 cents.* A review of experience over a considerable time with one type of small automatic circuit recloser indicated that some redesign of its operating characteristics was desirable. Time-lag tripping on all operations, as originally used, apparently is well suited to reclosers at most locations on a radial distribution system. However, the reclosers farthest from the substation can use advantageously instantaneous tripping on the first two operations, improving co-ordination with fuse links. High speed reclosing is used, following the first instantaneous tripping to reduce outage time and thereby keep line inrush low, so that the recloser will not retrip immediately. The paper discusses the problem of recloser time–current characteristics and describes a new recloser, readily changed in the field from one type of characteristic to another

47-59—The Interruption of Charging Current at High Voltage; *W. M. Leeds (M'38), R. C. Van Sickle (M'37). 30 cents.* This paper attempts to evaluate the effect of both the circuit constants and the characteristics of the various types of interrupters used in modern high-voltage oil circuit breakers on the magnitude of switching surges. Particular attention is given to the advantages and disadvantages of such special circuit breaker modifications as auxiliary oil flow pistons or low ohmic value resistors in parallel with the main arc-extinguishing devices.

47-60—Sectionalizing and Internal Transformer Fusing on Rural Power Circuits; *B. O. Watkins (M'46). 25 cents.* This paper shows how co-ordination is necessary between transformer fusing and line sectionalizing devices on rural electric systems in order to maintain adequate service. The differences between the characteristics of internal fuses in rural transformers of various manufacture are pointed out. The relations between the clearing time of different internal fuses to the opening time of various sectionalizing reclosers are tabulated. Suggestions are made for the improvement in rural electric service by standardization of internal fuse characteristics, revision of such characteristics and revision of recloser characteristics.

47-65—Grounding of Instrument Transformer Secondary Circuits; *An AIEE Committee Report. 15 cents.* Information received from a number of correspondents on practices in grounding of instrument transformer secondary circuits is summarized in this report. Single point and multipoint methods of grounding are defined and discussed; reasons for single point grounding and opinions on the preferred location of the ground point are listed; the need for periodic testing to detect open circuits, shortcircuits, accidental grounds, and deterioration of insulation is pointed out. Conclusions drawn from the investigation are presented as recommended preferred practices.

47-66—Fundamental Basis for Distance Relaying; *W. A. Lewis (F'45), L. S. Tippett. 30 cents.* For the protection of transmission lines against short circuits and ground faults, it is desirable to have a system of relays, which will divide all faults on the line it protects, regardless of type or system conditions, into two classes; one, those which occur between the relaying station and the next sectionalizing point on that line, and two, all other faults. It is also desirable that this classification be performed instantaneously, so that the section in trouble may be isolated immediately, thus reducing the damage at the point of fault and the shock to the remainder of the system, and in general permitting operation nearer the stability limit. The quantities which may be utilized for classification are currents, voltages, the phase relations between them, and time. The demand for high speed of fault isolation rendered acute by the development of high-speed circuit breakers largely has disqualified time as a fundamental means of discrimination, leaving only the other three.

47-67—Experience With Single-Pole Relaying and Reclosing on a Modern 132-Kv System; *J. J. Trainor, C. E. Parks (M'45). 20 cents.* This paper presents experience data, accumulated over a period of years, on the operation of single-pole relaying and reclosing as applied to five 132–kv transmission lines totaling 331 miles in length. Since the original installation was completed in March 1941, there have been a total of 59 faults experienced on the lines equipped with the single-pole switching features. Of these faults, 76.3 per cent involved only one phase and ground and successful single-pole reclosing was experienced in 84.4 per cent of the operations. Single-pole switching provides numerous advantages over multipole switching. Longer phase de-energization time is permitted, with no loss in system stability benefits, making for less chance of fault arc restrike. Single-pole operation under fault conditions results in negligible system voltage and power flow disturbance. Actual operating experience with this revolutionary form of switching has been very gratifying and has caused little trouble.

Servomechanisms

47-15—Dimensionless Analysis of Servomechanisms by Electrical Analogy—II; *G. D. McCann (M'44), S. W. Herwald (A'46). 25 cents.* The mechanical transients analyzer has provided a ready method for making generalized studies of the response characteristics of servomechanisms. This paper presents a continuation of such a study for angular-position, variable-voltage servomechanisms. In a previous paper, dimensionless curves were presented giving the optimum parameters and transient response characteristics of such servomechanisms with simple error control alone and with error control plus optimum anticipation time. This paper gives a similar analysis for error control servomechanisms having the three most important forms of *RC*-feedback damping; that is, feedback from generator field current, feedback from generator armature terminals, and feedback proportional to the velocity of the regulated system. The actual physical systems and the equations defining their performance are presented together with the electrical analogies set up on the analyzer.

47-52—Laboratory Aids for Electromechanical System Development; *G. C. Newton, Jr. (A'31), W. T. White. 15 cents.* Laboratory aids for development of electromechanical systems are described in this paper. Standardized components for mocking up complex electromechanical systems proved to be time-saving aids in laboratory work. Illustrations are shown of laboratory setups using these components, and descriptions are given of the more generally used mechanical and electronic components.

Television

47-75—A New Microwave Television System; *J. F. Wentz (M'42), K. D. Smith. 20 cents.* A microwave point-to-point radio system is described, which now is being produced for the transmission of television programs. This system augments wire facilities which previously have been used for local distribution of television from studio to broadcast transmitter or to long distance coaxial terminals. The circuits in the system and the equipment design are described in detail. Performance obtained on various installations of preproduction models during 1946 is given.

PERSONAL • • • • •

G. S. Timoshenko (A'33, M'39) formerly associate professor of electrical engineering, University of Connecticut, Storrs, has been appointed professor and head of the electrical engineering department of the university. Born in St. Petersburg, Russia, in 1904, Professor Timoshenko received an engineering degree from the Technische Hochscule Berlin, Charlottenburg, Germany, in 1929 and the degree of doctor of philosophy from the University of Michigan in 1932. After coming to the United States in 1929, he was employed by the Westinghouse Electric Corporation, East Pittsburgh, Pa., and since has been associated for brief periods with the General Electric Company, the United Aircraft Corporation, and the Templetone Radio Corporation. He was instructor in electrical engineering at Massachusetts Institute of Technology, Cambridge, from 1934 to 1939 and in 1939 joined the faculty of the University of Connecticut as assistant professor. He was made associate professor in 1943. He has been a member of the AIEE committee on basic sciences since 1943 and is a member of the executive committee of the Connecticut Section. He is the author of several technical papers on electric arcs, sputtering, and physical photometry.

W. R. G. Baker (A '19, M '41) vice-president in charge of electronics, General Electric Company, Syracuse, N. Y., has been elected president of the Institute of Radio Engineers. Doctor Baker was born in 1892 in Lockport, N. Y., and was graduated from Union College in 1916. He received the honorary degree of doctor of science from that institution in 1935. He was managing engineer of the radio department of the General Electric Company, Schenectady, N. Y., until 1930 and vice-president and general manager of the RCA Manufacturing Company, Camden, N. J., from 1930 to 1935. He was appointed manager of the radio and television department of the General Electric Company, Bridgeport, Conn., in 1936 and vice-president in 1941. At present he is chairman of the AIEE committee on electronics, director of the engineering department of the Radio Manufacturers Association, and member of the board of governors of the National Electrical Manufacturers Association.

J. A. Caparo (M '18, F '32) professor of electrical engineering, Notre Dame University, Notre Dame, Ind., has retired with the title of professor emeritus of electrical engineering. Doctor Caparo was born in Cuzco, Peru, in 1888 and received from Notre Dame University the degrees of civil engineer in 1908, electrical engineer and master of civil engineering in 1909, master of science in 1912, and mechanical engineer and doctor of philosophy in 1913. He also holds the degree of doctor of science (1910) from the University of Saint Anthony (Cuzco) and the degree of master of arts from the University of Chicago in 1919. He was instructor at Notre Dame University in 1908 and 1909 and professor of physics from 1913 to 1917. He was instructor at the Carnegie Institute of Technology in 1917–18. In 1918 he was named professor of electrical engineering and head of the department of electrical engineering. He resigned as head of the department in 1939. He has represented Peru at the Second Scientific Pan-American Congress in 1915 and at the Fifth Scientific Congress in Vancouver in 1932.

Samuel Ferguson (A '02) president of the Hartford (Conn.) Electric Light Company, has retired. However, he will continue as chairman of the board of the company. Mr. Ferguson, who was graduated from Trinity College in 1896, received the degrees of master of arts and electrical engineer from Columbia University in 1899. He commenced his career at the General Electric Company, Schenectady, N. Y., where he worked as research engineer and consultant in association with C. P. Steinmetz and W. R. Whitney (A '01). He joined the Hartford company as vice-president in 1912 and became president in 1924. He is a past president of the Association of Edison Illuminating Companies, and a trustee of the Edison Electric Institute and Trinity College. He is a director of the Arrow-Hart and Hegeman Electric Company, a trustee of the Western Massachusetts Companies, a member of the board of the Hartford Steam Boiler Inspection and Insurance Company, and he has served as president of the Connecticut Power Company. In 1936 he received the honorary degree of doctor of engineering from Rensselaer Polytechnic Institute.

F. E. Johnson (A '13, F '31) formerly dean of the college of engineering, University of Wisconsin, Madison, has been appointed head of educational activities at the Hanford engineer works of the General Electric Company, Richland, Wash. Mr. Johnson received the degree of bachelor of arts in 1906 and the degree of electrical engineer in 1909 from the University of Wisconsin. He was engaged in power plant construction in the state of Washington and in British Columbia until 1910 and was instructor at Rice Institute, Houston, Tex., from 1910 to 1915. He was a member of the faculty of the University of Kansas, Lawrence, from 1915 to 1930, resigning as head of the department of electrical engineering. He was head of the department of electrical engineering at Iowa State College, Ames, until 1935 at which time he became dean of the college of engineering of the University of Missouri, Columbia. He was appointed dean at the University of Wisconsin in 1938. He is a member of Tau Beta Pi, Sigma Xi, and Eta Kappa Nu.

H. E. Turner (A '26, M '41) formerly assistant general manager, Ohio Power Company, Canton, has been elected vice-president and general manager and a member of board of directors of the company. Born in Canada in 1902, Mr. Turner was graduated from the University of Toronto in 1924. After two years with the General Electric Company, Schenectady, N. Y., Mr. Turner became an engineer in the system protection section of the American Gas and Electric Service Corporation, New York, N. Y., in 1926, and in 1934 was made executive assistant to the vice-president and chief engineer. He went to the Ohio Power Company, a subsidiary of the American Gas and Electric Company, in 1941 as assistant general manager. He is a member of the Franklin Institute, the Society of American Military Engineers, and the Ohio Society of Professional Engineers.

D. G. Fink (M '45) formerly executive editor of *Electronics*, New York, N. Y., has become editor of that magazine. Mr. Fink, who holds the degree of bachelor of science (1933) from Massachusetts Institute of Technology and master of science (1943) from Columbia University, has been associated with the staff of *Electronics* since 1934. Between 1934 and 1941 he held the positions of editorial assistant, assistant editor, associate editor, and managing editor. He was loaned to the Radiation Laboratory at MIT, Cambridge, Mass., in 1941 and directed the development of the Loran navigation system. From 1943 to 1945 he was expert consultant in the office of the Secretary of War on the applications of aircraft navigation systems and ground based radar systems for the Army Air Forces. He returned to *Electronics* as executive editor in 1945. Mr. Fink is the author of a number of books on electronic subjects. He is a member of the Institute of Radio Engineers.

P. C. Magnusson (A '38) formerly assistant electrical engineer, Bonneville Power Administration, Portland, Oreg., has been been appointed assistant professor of electrical engineering at Oregon State College, Corvallis. Doctor Magnusson received the degree of bachelor of science from the University of Washington in 1937, the degree of master of science in 1938 from the University of California, and the degree of doctor of science in 1941 from Massachusetts Institute of Technology. From 1941 to 1943 he was assistant electrical engineer in the Naval Ordnance Laboratory, Washington, D. C. Commissioned in the United States Naval Reserve in 1943 and promoted to lieutenant in 1946, he was project officer in the Bureau of Ordnance, Washington, from 1943 to 1946. He joined the Bonneville administration in 1946.

R. J. Wensley (A '28, M '35) formerly general manager, I-T-E Circuit Breaker Company Philadelphia, Pa., has been appointed general manager of the Wilcox-Gay Corporation, Charlotte, Mich. Mr. Wensley commenced his career as switchboard design engineer for the Westinghouse Electric Corporation, East Pittsburgh, Pa., in 1916. As section head of the switchboard department after 1921 he pioneered many developments in supervisory and automatic control for hydroelectric generator and electric substations. From 1929 to 1931 he was correlator of the domestic refrigeration program and in 1931 was made chief engineer of the protective relay section. He became assistant general manager of the I-T-E company in 1935 and general manager in 1941. He is a member of the Institute of Radio Engineers and the Illuminating Engineering Society.

G. C. Boyer (A '32, M '36) formerly associate engineer, Burns and McDonnell Engineering Company, Kansas City, Mo., has joined the faculty of the Missouri School of Mines and Metallurgy, Rolla, as associate professor of mechanical engineering. Mr. Boyer, who holds the degree of mechanical engineer from Montana State College, commenced his career in the testing department of the General Electric Company, Schenectady, N. Y., in 1925, and was associated with the Kansas City (Mo.) Power and Light Company from 1926 to 1928. He was afterwards with the American Eagle Aircraft Corporation and Saul Aircraft Corporation before joining the Burns and McDonnell company in 1930. He is author of the book, "Diesel and Gas Engine Power Plants," and of a number of technical articles. He is a member of Tau Beta Pi.

E. R. Whitehead (A '30, F '45) formerly investigation engineer, Duquesne Light Company, Pittsburgh, Pa., has been appointed research professor of electrical engineering at the Illinois Institute of Technology, Chicago. Doctor Whitehead received the degree of bachelor of science from the University of Colorado in 1928 and the degrees of master of science in 1935 and doctor of philosophy in 1944 from the University of Pittsburgh. He joined the Duquesne company in 1932. As research supervisor, operating engineer, and finally investigation engineer, he conducted several surveys on lightning protective devices, developed a very sensitive system for automatic paralleling of separated power systems, and contributed to the development of system studies with the a-c network calculator.

E. H. Aiken (A '28, M '37) formerly service engineer, General Electric Company, Los Angeles, Calif., has been appointed superintendent of the service shop in Los Angeles. Mr. Aiken was graduated from Washington State College in 1922. He was employed by the Western Colorado Power Company, Durango, on transmission line and powerhouse construction and on the electrification of silver mines from 1922 to 1928. In 1928 he was associated with the Puerto Rico Railway Light and Power Company and afterwards with the Texas Power and Light Company, Dallas. Before joining the General Electric Company in 1940 he was chief engineer with the Imperial (Calif.) Irrigation District.

C. E. Bathe (A '29, M '35) formerly superintendent of engineering, Oklahoma Gas and Electric Company, Oklahoma City, has been appointed superintendent of the transmission department. Before joining the company in 1927, Mr. Bath was a member of the faculty of the University of Oklahoma. He had been superintendent of engineering since 1941. **R. E. Thornton** (M '32) formerly distribution engineer for the company, succeeds Mr. Bathe as superintendent of engineering. Mr. Thornton has been with the company since he was graduated from the University of Oklahoma in 1925. **Bryce Brady** (A '29, M '37) formerly of the engineering department has been named distribution engineer. A 1927 graduate of the University of Oklahoma, Mr. Brady has been with the company since his graduation.

N. R. Gibson (M '35) vice-president, Buffalo (N. Y.), Niagara Electric Corporation, has been awarded the Holley Medal of the American Society of Mechanical Engineers "for his achievements and inventions which have advanced the science of hydraulics and hydromechanics, including an original method of water measurement which made possible more accurate testing of large hydroelectric generating units." Mr. Gibson was born in Guelph, Ontario, Canada, in 1880, and was graduated from the University of Toronto. He has been with the Buffalo Niagara group of companies since 1925. He received the Elliott Cresson gold medal of the Franklin Institute in 1930 and the honorary degree of doctor of engineering from the University of Toronto in 1931.

H. H. Glenn (M '28) member of the technical staff of Bell Telephone Laboratories, Inc., has retired. Mr. Glenn joined the Bell System in 1909 after receiving the degree of bachelor of science from Pennsylvania State College when he entered the student training course of the Hawthorne plant of the Western Electric Company, Chicago. The following year he was transferred to the physical laboratory in New York. He was placed in charge of the development of cords, wire, and switchboard cables in 1920. Air-conditioning development work was added to his responsibility in 1924, and lamps, batteries, and sealed terminals in 1940.

C. A. Mullen (A '20, M '20) formerly general superintendent of operations, Jersey Central Power and Light Company, Asbury Park, N. J., has been appointed vice-president in charge of operations. After a period with the Ohio Electric Railway Company and Penn Central Power and Light Company, Mr. Mullen became electrical engineer for the Ohio Service Company, Zanesville, in 1914. He was appointed superintendent of substations for the Pennsylvania Power and Light Company, Hazleton, Pa., in 1924. He became superintendent of operations of the Eastern New Jersey Power Company at Asbury Park, in 1927 and, when that company was purchased by the Jersey Central company in 1931, he was made superintendent of the Morristown division. He was appointed general superintendent of operations in 1945.

Edwin Fleischmann (A '22, M '29) formerly consultant, Gilbert Associates, Inc., New York, N. Y., has established a consulting engineering office in Palo Alto, Calif. During the war Mr. Fleischmann was Deputy Chief of the Fuel and Allocations Branch, Office of War Utilities, War Production Board, Washington, D. C. Previously he had been associated from 1927 to 1942 with the Niagara Hudson System in Buffalo and Niagara Falls, N. Y.

H. J. Oorthuys (A '35) formerly of the United States Navy Radio and Sound Laboratory, San Diego, Calif., has been appointed assistant professor of electrical engineering at Purdue University, Lafayette. Professor Oorthuys received the degrees of bachelor of science in 1934 and master of science in 1938 from Oregon State College. From 1940 to 1943 he was an instructor in electrical engineering at Oregon State College, Corvallis, and in 1944 joined the Radio Laboratory.

K. P. Applegate (A '14) formerly vice-president and general manager, Hartford (Conn.) Electric Light Company, has been appointed to the newly created office of executive vice-president of the company. Mr. Applegate joined the company in 1912 following his graduation from Rensselaer Polytechnic Institute. He became power salesman and in 1916 was made purchasing agent. He was named general manager in 1929 and vice-president in 1943. Mr. Applegate was chairman of the utilities division of the Hartford War Council.

M. M. Cory (A '15, F '40) professor of electrical engineering, Michigan State College, East Lansing; and **E. R. Moore** (M '40) assistant to the chief engineer, Detroit (Mich.) Edison Company, have been elected members of the executive council of Tau Beta Pi. **M. E. Van Valkenburg** (A '45) of the electrical engineering department, University of Utah, Salt Lake City, has been appointed national chapter co-ordinator for the society.

M. E. Leeds (A '01, F '26) chairman of the board, Leeds and Northrup Company, Philadelphia, Pa., has been awarded the ASME Medal, the highest honor of the American Society of Mechanical Engineers. The medal, which is awarded annually for distinguished service in engineering and science, was bestowed upon Mr. Leeds for "outstanding achievements in the invention and development of electrical and temperature measuring instruments and accomplishments in the field of industrial relations."

W. R. Nodder (A '38) formerly engineer for the General Air Conditioning and Heating Company, Oakland, Calif., has joined the George E. Honn Company, manufacturers representatives, San Francisco, Calif. Mr. Nodder, who was released from the Army as a lieutenant colonel in March 1946, during the war was instructor in antiaircraft artillery school at Camp Davis, N. C., searchlight battalion commander in the Hawaiian Islands, and staff officer, Headquarters of the Army Air Forces in the mid-Pacific.

P. Dunsheath (M '22) director and chief engineer, W. T. Henley's Telegraph

Works Company, Ltd., London, England, has retired from that position. Doctor Dunsheath will continue as consulting engineer and retains a seat on the boards of the parent company and its subsidiaries. He joined the company in 1919 to reorganize the research department and was appointed research and technical manager in 1929. He became chief engineer in 1934 and was elected a director in 1937.

E. E. Scofield (A '43) manager of wholesale and special contracts, Washington Water Power Company, Spokane, has joined the Lee F. Austin Company, Spokane. Mr. Scofield had been with the Washington Power company since 1922 and had held the positions of engineer in the commercial department, industrial engineer, manager of industrial sales, assistant to the manager of the rate department, superintendent of power contracts and statistics, and power consultant.

H. W. Hitchcock (A '15, F '37) chief engineer, Southern California Telephone Company, Los Angeles, recently was presented with the Medal of Freedom for rendering exceptionally meritorious service to the American Armies in his capacity as civilian technical adviser to the chief signal officer in the European theater of operations.

O. E. Mace (A '33) formerly associated with Howard P. Foley, Inc., Baltimore, Md., now is vice-president of the consulting engineering firm of Timanus and Associates, Baltimore. **A. H. Sonon** (A '29) formerly chief engineer, Maryland Engineering Company, Baltimore, also has become an associate in the firm.

J. S. Parry (A '40) formerly manager, Westinghouse Electric Corporation, Newark, N. J., has been appointed Eastern district industrial manager. Mr. Parry joined the company in 1920 as a graduate student and has held sales positions in the New York and Newark offices. He has been manager since 1941.

L. H. Cleary (A '20, F '42) technical director for the National Electrical Contractors Association, Washington, D. C., has been nominated as treasurer of the National Society of Professional Engineers. Mr. Cleary was awarded the Army and Navy E Award for work on the United States Signal Corps School Project, Arlington, Va., in 1943.

E. W. Hewett (A '38) deputy borough electrical engineer, Tunbridge Wells, Kent, England, has been appointed deputy electrical engineer and manager of the Bolton Corporation Electricity Department. Mr. Hewett was with the Central Electricity Board from 1933 to 1938 at Bristol and London and with the Preston Corporation Electricity Department as mains engineer from 1938 to 1946.

L. K. Sillcox (M '19, F '31) first vice-president, New York Air Brake Company, Watertown, N. Y., recently was awarded honorary membership in the American Society of Mechanical Engineers for "his eminence as an engineer and executive and as a distinguished lecturer and inspirer of men."

A. G. Stanford (M '28) of Robert and Company, Inc., Atlanta, Ga., has been nominated as vice-president for the Southern area of the National Society of Professional Engineers.

J. A. Herrmann (A '41) formerly field engineer, Bull Dog Electric Products Company, Detroit, Mich., has been appointed director of engineering of that organization. Mr. Herrmann served for three years in the General Industrial Equipment Division of the War Production Board and afterwards undertook a mission to Germany for the Technical Industrial Investigating Committee.

E. N. Nelson (M '41) formerly assistant general production engineer, Ohio Public Service Company, Cleveland, has been appointed system production engineer. Mr. Nelson, who joined the Ohio company in 1924, was transferred to the Cleveland office from the central station engineering department, Elyria in 1945.

J. B. Clapp (A '24, M '38) formerly sales engineer, Thomas and Betts Company, Elizabeth N. J., has been appointed manager of the company's utilities division. Mr. Clapp has been with the company since 1944.

M. K. Kofoid (A '35, M '43) formerly research engineer, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed to the faculty of the electrical engineering department of Oregon State College, Corvallis.

W. L. Thrailkill (M '42) assistant general manager, Washington Water Power Company, Spokane, has been nominated as vice-president for the Western area of the National Society of Professional Engineers.

J. F. Fairman (A '20, F '35) vice-president, Consolidated Edison Company of New York (N. Y.), Inc., and AIEE vice-president, has been nominated as vice-president for the Eastern area of the National Society of Professional Engineers.

H. C. Graves, Jr. (A '23, M '43) formerly electrical engineer, I-T-E Circuit Breaker Company, Philadelphia, Pa., has been appointed chief engineer of the Gibson Electric Company, Pittsburgh, Pa.

R. H. Barclay (A '14, F '28) chief electrical engineer, electrical engineering department, J. G. White Engineering Corporation, New York, N. Y., has been elected chairman of the Engineering Societies Library Board.

E. L. Swords (A '26) acting manager for the Santa Maria, Calif., district of the Pacific Gas and Electric Company, has been named district manager. Mr. Swords has been with the company since 1927.

William Kelly (F '25) chairman of the executive committee, Buffalo (N. Y.) Niagara Electric Corporation, has been appointed Buffalo community chairman for the Committee of Economic Development.

N. H. Meyers (A '41) formerly of the central station engineering department, General Electric Company, Schenectady, N. Y., has been transferred to Spokane, Wash., as sales manager of the company's office in that city. He was graduated from Washington State College in 1938.

H. M. Gustafson (A '26, M '41) formerly sales engineer, General Electric Company, Seattle, Wash., has been appointed assistant manager of the apparatus department in the Seattle office.

C. R. Wallis (A '20, M '26) formerly of the central station department, General Electric Company, Seattle Wash., has become Northwest district manager of the transportation division.

E. C. Curtis (A '31) formerly district switchgear specialist, General Electric Company, Portland Oreg., has been appointed manager of the central station division for the Northwest district of the company.

G. R. Henninger (F '43) AIEE editor, has been elected to the Borough Council of Haworth, N. J., for the term beginning January 1, 1947. Mr. Henninger was president of the Board of Education and trustee of the Municipal Library when he went on active military duty in 1942.

C. G. Mills (A '28) formerly electrical engineer, West Kootenay Power and Light Company, Trail, British Columbia, Canada, is now with the engineering division of the British Columbia Electric Railway Company, Ltd., Vancouver.

R. W. Graham (A '18 M '31) electrical, superintendent, Bethlehem Steel Company Lackawanna, N. Y. has been elected chairman of the Buffalo district section of the Association of Iron and Steel Engineers.

C. H. Leatham (A '33) vice-president, Monongahela West Penn Public Service Company, Fairmont, W. Va., has been elected president of the Public Utilities Association of the Virginias.

W. H. Kerr (A '31) formerly district manager, Pacific Gas and Electric Company, Oakdale, Calif., has been transferred to Lodi, Calif., as district manager.

G. R. Anderson (A '22, M '29) formerly chief engineer, electrical division, Fairbanks, Morse and Company, Beloit, Wis., has been made director of engineering.

H. H. Marsh, Jr. (A '27, M '41) formerly assistant general superintendent of substations and shops, Duquesne Light Company, Pittsburgh, Pa., has been appointed superintendent. He has been with the company since 1922 and holds the degrees of bachelor of arts (1919) from Marietta College and electrical engineer (1922) from Lehigh University.

Quentin Graham (A '39) formerly manager of the electrical engineering department, Elliott Company, Ridgway, Pa., has been appointed manager of the Ridgway division of the company. Mr. Graham was graduated from Oklahoma Agricultural and Mechanical College in 1914 and from that time until 1944 was associated with the Westinghouse Electric Corporation.

H. B. Sargent (M '40) formerly executive vice-president of the Central Arizona Light and Power Company, Phoenix, has been elected president of the company. Mr. Sargent, who became executive vice-president of the company in 1946, previously was vice-president and general manager of the Mississippi Power and Light Company, Jackson.

I. E. Moultrop (A '10, F '29) of Belmont, Mass., retired chief engineer, Edison Electric Illuminating Company of Boston (Mass.), has been made an honorary member of the American Society of Mechanical Engineers. Mr. Moultrop has been honored for "his engineering leadership in the installation of high-pressure steam generating power equipment in the United States."

G. P. Hobbs (A '41) formerly electrical engineer with the Marathon Paper Mills of Canada, at Toronto and Marathon, Ontario, has been appointed electrical engineer with Bowater's Newfoundland Pulp and Paper Mills, Corner Brook. Mr. Hobbs, who was born in Newfoundland, was graduated from McGill University in 1940.

H. C. Anderson (A '23, M '32) formerly lieutenant colonel, United States Army, has returned to his position in the electrical engineering department of the Consolidated Edison Company of New York (N. Y.), Inc. Colonel Anderson served as Post Signal Officer at Indiantown Gap (Pa.) Military Reservation, from 1942 to 1946. For meritorious service as Signal Officer he was awarded the Army Commendation Ribbon.

H. L. Rusch (A '24) formerly Central States manager, Public Opinion Index for Industry, Chicago, Ill., has been appointed vice-president of the Opinion Research Corporation, Princeton, N. J. Mr. Rusch joined the organization in March 1946 (*EE, June '46, p 287*).

O. C. Schlemmer (A '30, M '39) who has been serving as a captain in the United States Army, has returned to the American Telephone and Telegraph Company, New York, N. Y., and is in the personnel relations department.

H. W. DeWitt (M '40) formerly engineer in the operating and results section of the operation and engineering department, American Telephone and Telegraph Company, New York, N. Y., has been placed in charge of the appraisal practices group.

Chester Wallace (A '33) special representative in the administration department, American Telephone and Telegraph Company, New York, N. Y., has completed 40 years of service with the company. **R. E. Wolff** (A '12) has completed his 35th year.

A. L. Thurman (A '38, M '45) formerly chief electrical engineer, Aetna-Standard Engineering Company, Youngstown, Ohio, has been appointed assistant to the vice-president. Mr. Thurman had been chief electrical engineer since December 1945 (*EE, Apr '46, p 177*).

E. D. T. Norris (A '24, F '30) chief engineer, transformer department, Ferranti, Ltd., Hollenwood, England, has been elected chairman of the North Western Center of the Institution of Electrical Engineers.

J. S. Murray (A '21, M '31) district sales manager, Alliance Machine Company, Pittsburgh, Pa., has been appointed district secretary of the Pittsburgh district section of the Association of Iron and Steel Engineers.

F. A. Coles (M '41) formerly lieutenant colonel and technical executive officer, Signal Laboratory, Camp Evans, N. J., has returned to Bell Telephone Laboratories, Inc., New York, N. Y. He had been on active duty since 1942.

H. H. Schroeder (A '32) formerly staff assistant, personnel relations department, American Telephone and Telegraph Company, New York, N. Y., has been transferred to the Michigan Bell Telephone Company, Detroit, and appointed personnel relations assistant.

G. W. Vinal (M '19, F '42) physicist and chief of the electrochemistry section of the National Bureau of Standards, Washington, D. C., has been elected president of the Weston cell committee of the International Union of Chemistry.

R. H. Hopkins (A '22, M '33) engineer in the operations and engineering department of the American Telephone and Telegraph Company, New York, N. Y., recently completed 35 years of service with the company.

C. M. Mapes (M '40) formerly systems engineer in the operation and engineering department, American Telephone and Telegraph Company, New York, N. Y., has been appointed plant extension engineer.

D. A. Lewis (M '35) formerly operating superintendent of the western division, New York State Electric and Gas Corporation, Lancaster, has been appointed eastern division manager.

H. D. Brown (M '43) formerly engineer in charge of the power rectifier department, General Electric Company, Schenectady, N. Y., has been made manager of the power electronics division.

John Morse (A '09) vice-president in charge of operation, Shawinigan Water and Power Company, Montreal, Quebec, Canada, has been appointed Canadian member of the international executive committee of the International Conference on Large Electric High-Voltage Systems. Mr. Morse is also president of the Canadian National Committee of CIGRE.

N. E. Funk (A '07, F '34) vice-president, engineering and operation department, Philadelphia (Pa.) Electric Company, has been named vice-president for region III of the American Society of Mechanical Engineers.

C. J. Fechheimer (A '05, F '14) formerly consulting engineer, The Louis Allis Company, Milwaukee, Wis., has started and independent consulting practice in Milwaukee.

OBITUARY

Alexander Stanley Garfield (A '98, M '01, F '13) AIEE local honorary secretary and chief engineer. French Thomson-Houston Company, Paris, France, died December 5, 1944, in Zug, Switzerland. Mr. Garfield was born March 3, 1866, in Detroit, Mich., and was graduated from Massachusetts Institute of Technology with the degree of bachelor of science in mechanical engineering in 1887. He also completed a postgraduate course in civil engineering. After several months in the repair shops of the Union Pacific Railroad, Omaha, Nebr., he joined the Thomson Electric Welding Company, West Lynn, Mass., in 1888, and in 1890 was made engineer in charge of design and construction of electric machinery for the Thomson Company and the General Electric Company. In 1893 he was sent abroad as engineer in charge of manufacture and joined the French Thomson-Houston company in that capacity. He was appointed chief engineer in 1900. He also was named consulting engineer to the Mediterranean Thomson-Houston Company. In these positions he was in charge of the electrification of many of the French railroads, and was responsible for installations in Italy and Germany. He was a member of the Institution of Electrical Engineers. Mr. Garfield had served as AIEE local honorary secretary from 1914 until his death.

Adolph Rudolph Swoboda (A '06, M '26) retired member of the staff of Bell Telephone Laboratories, New York, N. Y., died October 20, 1946, in Newark, N. J. Born April 5, 1880, in Vienna, Austria, he received the degree of bachelor of science in electrical engineering in 1903 from the University of Nebraska. He entered the student's course at the Western Electric Company, in 1903 and remained as an apprentice in Chicago, Ill., and New York until 1905. He was instructor in electrical engineering at the University of Nebraska, Lincoln, from 1905 to 1907. Following a period with the Kellogg Switchboard and Supply Company, Chicago, he returned to the Western Electric Company as engineer in the physical laboratory. He was for a time in the telegraph development department and then in the apparatus design group. When Bell Laboratories was formed in 1925 he was titled apparatus development engineer. Mr. Swoboda was granted a number of patents for his design work.

John James Kane (M '15) patent attorney, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., died November 8, 1946. He was born November 20, 1882, in Worcester, Mass., and was graduated from Worcester Polytechnic Institute with the degree of bachelor of science in electrical engineering in 1905. In 1909 he received the degree of bachelor of laws from Georgetown University and the degree of master of patent law in 1910. After a few months with the Providence (R. I.) Telephone Company and the American Steel and Wire Company, Worcester, he became an assistant patent examiner in the United States Patent Office. He joined the Allis-Chalmers company as patent attorney in 1912 and in 1944 was appointed head of the patent department. Mr. Kane was past president of the Milwaukee Patent Law Association and a member of the American Patent Law Association and the American Bar Association.

Eugene Viele Griffes (A '96) electrical engineer, Palm Springs, Calif., died July 21, 1945. Mr. Griffes was born September 28, 1868, in Schenectady, N.Y., and attended the University of Southern California. He commenced his electrical career in Schenectady with the Edison General Electric Company, predecessor of the General Electric Company. After completing the student's course he was associated with the Schenectady Street Railway and Illuminating Company. He was partner in the contracting firm of Griffes and Summer, Los Angeles, Calif., from 1894 to 1899. From 1899 to 1904 he was manager of the electrical lighting and water gas plants for the United Electric Gas and Power Company, Long Beach, Calif., and in 1904 was made general manager of the Oceanside Electric and Gas Company. Since 1916 he had been a consulting engineer.

Joseph Mini, Jr. (A '08) retired engineer of Los Gatos, Calif., died August 23, 1946. Mr. Mini was born February 4, 1879, in Höritz, Austria, and was graduated from Stanford University with the degree of bachelor of arts in 1905. He was associated for a time with the San Mateo Power Company and the California Gas and Electric Corporation in San Francisco and in 1910 was made superintendent of the Colgate power division of the Pacific Gas and Electric Company. He was in the electrical construction department from 1915 to 1919 and then was transferred to the engineering department. From 1920 until his retirement in 1942 he was assistant chief of the division of hydroelectric and transmission engineering.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meeting of November 21, 1946, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute.

To Grade of Fellow

Bewley, L. V., head, elec. engg. dept., Lehigh University, Bethlehem, Pa.
Brainerd, J. G., professor, Moore School of Elec. Engg., Univ. of Pennsylvania, Philadelphia, Pa.
Brown, H. F., asst. elec. engr., N. Y., N. H., & H. R. R. Co., New Haven, Conn.
Feder, J. B., comdr., USCGR, principal elec. engr., U. S. Coast Guard, Washington, D. C.
Linville, T. M., elec. engr., motor & generator engg. div., General Elec. Co., Schenectady, N. Y.
Mahoney, H. P., chief consulting engr., Automatic Elec. Co.; chief engr., Associated Tel. & Tel. Co., Chicago, Ill.
Sundius, H. W., equipment engr., Southern New England Tel. Co., New Haven, Conn.
Trickey, P. H., chief engineer, Diehl Mfgr. Co., Finderne plant, Somerville, N. J.

8 to grade of Fellow

To Grade of Member

Benser, W. M., senior testman, Consolidated Gas Elec. Lt. & Pr. Co. of Baltimore, Baltimore, Md.
DeWild, J. A., instructor, elec. engg., Iowa State College, Ames, Iowa.
Dalton, B. J., industrial engg. divs., General Elec. Co., Schenectady, N. Y.
Dreyer, W. C., engg. & service mgr., Westinghouse Elec. Corp., Houston, Tex.
Edmunds, W. M., engr., office of chief, engg. div., REA–USDA, Washington, D. C.
Giles, M. A., supervising engr., central engg. dept., Ohio Public Service Co., Elyria, Ohio.
Grillo, J., electrical engr., Ward Leonard Elec. Co., Mount Vernon, N. Y.
Hayes, T. B., partner, Cornell, Howland, Hayes & Merryfield, consulting engrs., Corvallis, Oreg.
Hoffman, R. C., senior elec. engr., Fisher Body div., works engg. dept., General Motors Corp., Detroit, Mich.
Johnson, F. D., elec. design engr., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Kiekhaefer, E.C., vice-pres. & genl. mgr., Kiekhaefer Corp., Cedarburg, Wis.
Kitzmiller, M. W., designer, transp. motor engg. div., General Elec. Co., Erie, Pa.
Kraybill, E. K., asst. prof. of elec. engg., Duke University, Durham, N. C.
Lane, A. H., engineer, long lines plant dept., American Tel. & Tel. Co., Philadelphia, Pa.
Lindberg, H. C., engr., General Elec. Co., Buffalo, N. Y.
Love, E. R., asst. prof. of elec. engg., University of Manitoba, Winnipeg, Man., Canada.
Magnusson, P. C., asst. prof. of elec. engg., Oregon State College, Corvallis, Oreg.
McArthur, D., Simplex Wire & Cable Co., Cambridge, Mass.
McCrumm, J.D., associate prof. of elec. engg., Swarthmore College, Swarthmore, Pa.
Ott, M. G., engineer, Board of Public Utilities, Kansas City, Kans.
Pomazal, J. W., elec. engineer, Kurz & Root, Appleton, Wis.
Price, E. R., central station engineer, Westinghouse Elec. Corp., Amarillo, Tex.
Rowland, J. F., elec. engr., III, Tennessee Valley Authority, Chattanooga, Tenn.
Shipp, E. C., owner, Shipp Elec. Co., Midvale, Utah.
Spielman, W. L., elec. engr., S. C. Sachs Co., St. Louis, Mo.
Stalnecker, F. I., supt. of power, Cities Service Refining Corp., Lake Charles, La.
Woods, F. L., design engr., network section, General Elec. Co., Pittsfield, Mass.

27 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before January 21, 1947, or March 21, 1947, if the applicant resides outside of the United States, Canada, or, Mexico.

To Grade of Member

Belock, H. D., Reeves Instrument Corp., New York, N. Y.
Brogan, F. C., The Ohio Public Service Co., Elyria, Ohio.
Chowdbury, N. C. D., H. Datta & Sons, Ltd., Calcutta, India.
Cushing, I. M. (re-election), Hollis French, Boston, Mass.
Drake, C. O., Elec. Products Cons., Salt Lake City, Utah.
Durham, A. C., U. S. Bureau of Mines, Wilkes-Barre, Pa.
Evans, E. N., Messrs. Hocking & Orchard, Ltd., Bristol, England.
Hasty, V. R., Union Pacific Railroad Co., Omaha, Nebr.
Hyvarinen, J., U. S. Bureau of Mines, Salt Lake City, Utah.
Johnston, V. C., Consolidated Edison Co., L. I. City, N. Y.
Jones, O. M., Appalachian Elec. Pr. Co., Charleston, W. Va.
Kimball, C. B., Boston Edison Co., Boston, Mass.
Kvist, A. E. K., Allmanna Svenska Elect. A/B, Ludvika, Sweden.
Maas, F. J., Bonneville Pr. Adm., Portland, Oreg.
Machael, R. L., B. M. Dornblatt & Associates, Inc., New Orleans, La.
Martz, J. V., Int'l Business Machines Corp., Endicott, N. Y.
Moffitt, G. E., Okonite Callender Cable Co., Paterson, N. J.
Moore, A. G., 1440 St. Catherine St. W., Montreal, Que., Canada.
Nelson, V. H. G., U. S. Army Air Forces, AMC, Wright Field, Dayton, Ohio.
Newman, E. V., General Elec. Co., Toledo, Ohio.
Pearson, F. L., Rm. 1310, Majestic Bldg., Detroit, Mich.
Poor, R. L., Beach Elec. Co., Newark, N. J.
Prentice, B. R., General Elec. Co., Schenectady, N. Y.
Proudfoot, W. B., Rwy. & Pr. Engg. Corp., Ltd., Montreal, Que., Canada.
Rea, W. T., Bell Tel. Labs, Inc., New York, N. Y.
Skinner, S., Southwestern Bell Tel. Co., Kansas City, Mo.
Skinner, J. C., Interstate Theatres, Inc., Dallas, Tex
Smith, P. D., Canadian Westinghouse Co., Ltd., Vancouver, B. C., Canada.
Venables, T., Austin Co., Cleveland, Ohio.

29 to grade of Member

To Grade of Associate

United States and Canada

1. North Eastern

Bergstrom, A. G., Boston Edison Co., Boston, Mass.
Chambers, A. L., Jr., General Elec. Co., Schenectady, N. Y.
Gerosa, J. S., Westinghouse Elec. Corp., South Boston, Mass.
Hutton, R. E., Gleason-Avery, Inc., Auburn, N. Y.
Iddings, H. G., Jr., Cornell Aeronautical Lab., Buffalo, N. Y.
McKearin, J. G., Western Mass. Elec. Co., Springfield, Mass.
Murray, T. J., General Elec. Co., Schenectady, N. Y.
Noon, M. E., General Elec., Pittsfield, Mass.
Osborne, R. A., General Elec. Co., Rochester, N. Y.
Osthagen, S. O. M., Allis-Chaliners Mfg. Co., Boston, Mass.
Penard, F. P., Allis-Chalmers Mfg. Co., Hyde Park, Mass.
Ryan, J. M., Chas. T. Main, Inc., Boston, Mass.
D. N., U. S. Rubber Co., Chicopee Falls, Mass.

Stancu, G. S., General Elec. Co., West Lynn, Mass.
Walton, E. H., The United Illuminating Co., New Haven, Conn.
Whitford, J. R., General Radio Co., Cambridge, Mass.

2. Middle Eastern

Berthold, P. W., Berthold Elec. & Engg. Co., Akron, Ohio.
Bohn, C. R., Hq. Air Matériel Command, Wright Field, Dayton, Ohio.
Brook, F. D., The Ohio Pr. Co., Canton, Ohio.
Burns, M. J., B. F. Goodrich Co., Akron, Ohio.
Cavanna, W., United Engr. & Cons., Inc., Philadelphia, Pa.
Coffman, O. G., Robbins & Myers, Inc., Springfield, Ohio.
Doughty, H. C., The Ohio Pr. Co., Canton, Ohio.
Duboc, W. T., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Ferguson, W. B., Cleveland Elec. Illuminating Co., Cleveland, Ohio.
Fladd, A. J. J., Philadelphia Elec. Co., Philadelphia, Pa.
Friedman, M., Hertner Elec. Co., Cleveland, Ohio.
Gladen, L. C., Lincoln Elec. Co., Cleveland, Ohio.
Griffes, M. W., Elec. Controller & Mfg. Co., Cleveland, Ohio.
Hesse, W. E., Warner Elevator Mfg. Co., Cincinnati, Ohio.
Hill, F. E., Dayton Pr. & Lt. Co., Dayton, Ohio.
Hsu, S. C., Natl. Resources Comm. of China, c/o Gilbert Associates, Inc., Reading, Pa.
Krammes, D. C., Hoover Cleaner Co., North Canton, Ohio.
Kindelberger, K. H., The Ohio Pr. Co., Canton, Ohio.
Krawchuk, J. A., Philadelphia Elec. Co., Philadelphia, Pa.
Leslie, W. M., Westinghouse Elec. Corp., Sharon, Pa.
Mang, C.-Y., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Mathews, J. M., Allis-Chalmers Mfg. Co., Charleston, W. Va.
Miller, H. W., Ohio Edison Co., Youngstown, Ohio.
Mills, H. S., Philadelphia Elec. Co., Philadelphia, Pa.
Moody, W. R., National Radio Institute, Washington, D. C.
Moran, D. L., 1925 Riverside Drive, Dayton, Ohio.
Munn, J. M., Federal Pr. Comm., Washington, D. C.
Pack, G. A., I-T-E Circuit Breaker Co., Philadelphia, Pa.
Paine, C. W., Jr., The Ohio Pr. Co., Zanesville, Ohio.
Pennell, J. H., Ohio Pr. Co., Philo, Ohio.
Peters, H. E., Bell Tel. Co. of Pa., Pittsburgh, Pa.
Price, C. D., Jr., Columbus & Southern Ohio Elec. Co., Columbus, Ohio.
Price, G. A., Westinghouse Elec. Corp., Pittsburgh, Pa.
Robertson, J. A., The Chesapeake and Potomac Tel. Co., Washington, D. C.
Schalck, H. J., Gilbert Associates, Inc., Reading, Pa.
Schlasman, M. J., Metropolitan Edison Co., Reading, Pa.
Schmidt, P. L., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Sever, R. G., Ohio Pr. Co., Canton, Ohio.
Soslowski, T. P., University of Dayton, Ohio.
Strehle, F. E., Phila. Elec. Co., Philadelphia, Pa.
Tai, P. T., Natl. Resources Comm. of China, c/o Gilbert Associates, Reading, Pa.
Tombaugh, S. J., General Elec. Co., Toledo, Ohio.
Winitsky, H. B., Phila. Elec. Co., Philadelphia, Pa.

3. New York City

Bevilacqua, F., Sperry Gyroscope Co., Inc., Great Neck, N. Y.
Blake, J. E., 298 Roselle Ave., Cedarhurst, N. Y.
Brown, W. G., Electrons, Inc., Newark, N. J.
Dunlap, R. E., USASC, Signal Corps Board, Fort Monmouth, N. J.
Gilmore, J. P., M. W. Kellogg Eng. Co., Jersey City, N. J.
Given, I. K., RCA Communications, Inc., N. Y., N. Y.
Larlee, D. H. (re-election), American Bank Note Co., N. Y., N. Y.
Moore, J. H., A. T. & T. Co., New York, N. Y.
Morrell, C. R., Board of Transportation, New York, N. Y.
Nicot, P. V., The Lummus Co., New York, N. Y.
Quigley, E. J., Allied Chemical & Dye Corp., New York, N. Y.
Rose, H. B. (re-election), N. Y. Tel. Co., Brooklyn, N. Y.
Sculco, J. A., Krey & Hunt, New York, N. Y.
Schultz, G. F., Syska & Hennessy, New York, N. Y.
Smith, W. A., Public Service Elec. & Gas Co., Newark, N. J.
Thut, W. W., Brown Boveri Corp., New York, N. Y.
Tobey, S. B., Jr., Western Elec. Co., Kearny, N. J.
Tobin, T. J., Western Elec. Co., New York, N. Y.
Westerman, R. G. (re-election), War Assets Administration, New York, N. Y.

4. Southern

Allen, L. D., Shaw Hardy Co., Miami, Fla.
Askew, M., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Buck, H. N., Southern Bell Tel. & Tel. Co., Jackson, Miss.
Casey, C. A., Inst. of Textile Tech., Charlottesville, Va.
Cox, W. A., General Elec. Co., Birmingham, Ala.
Dibble, G. L., Jr., So. Carolina Pr. Co., Charleston, S. C.
Goodroe, C. R., TVA, Wilson Dam, Ala.
Greenhill, J. I., Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Hadfield, A. S., Virginia Elec. & Pr. Co., Alexandria, Va.
Lee, C. F., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Lozes, J. P., Jr., New Orleans Public Service, New Orleans, La.
Maloney, J. A., Nat'l Advisory Comm. for Aeronautics, Langley Field, Va.
Manning, T. J., The Okonite Co., Birmingham, Ala.
Owen, W. E., Louisiana State University, Baton Rouge, La.
Pool, V. R., TVA, Chattanooga, Tenn.
Roberts, E.D., Roberts Elec. & Appliance Co., Athens, Ga.
Schrader, H. W., University of Florida, Gainesville, Fla.
Spurlock, H. G., Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Steiner, M., Jr., Higgins, Inc., New Orleans, La.
Stephenson, C. E., R. J. Reynolds Tobacco Co., Winston-Salem, N. C.
Tims, E. F., Louisiana State University, Baton Rouge, La.
Towles, L. H., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Whitten, R. C., General Elec. Co., Louisville, Ky.
Willard, F. R., N. C. State College, Raleigh, N. C.
Winn, J., So. Carolina Pr. Co., Charleston, S. C.
Yarbrough, R. D., Southern Bell Tel. & Tel. Co., Birmingham, Ala.

5. Great Lakes

Anderson, H. L., Sargent & Lundy Engineers, Chicago, Ill.
Bell, W. P., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Duhm, W. T., Indianapolis Pr. & Lt. Co., Indianapolis, Ind.
Elwell, W. W., Amer. Tel. & Tel. Co., Chicago, Ill.
Elvis, J. C., Amer. Tel. & Tel. Co., Chicago, Ill.
Guthrie, G. R., Indianapolis Pr. & Lt. Co., Indianapolis, Ind.
Hagg, H. A., Northern States Pr. Co., Minneapolis, Minn.
Hudson, C. A., Bradley University, Peoria, Ill.
L'Amie, R. W., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Mann, J. R., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Moses, B. W., Hancock County R.E.M.C., Greenfield, Ind.
Raudenbush, D. H., Engg. Research Associates, Inc., St. Paul, Minn.
Rutkowski, A. A., Harnischfeger Corp., Milwaukee, Wis.
Simmons, A. N., The Detroit Edison Co., Detroit, Mich.
Spink, R. F., South Bend Elec. Co., Inc., South Bend, Mich.
Wilson, E., Nishnabotna Valley Rural Elec. Co-op., Harlan, Iowa.
Youngblood, J. T., Sangamo Elec. Co., Springfield, Ill.
Zimmerman, H. F., Engineering Research Associates, Inc., St. Paul, Minn.

6. North Central

Forchtner, J., Northwestern Bell Tel. Co., Omaha, Nebr.
Graham, W. F., Bureau of Reclamation, Denver, Colo.
Leh, M. C., Jr., Public Service Co. of Colo., Denver, Colo.
Lof, A. F., Northwestern Bell Tel. Co., Omaha, Nebr.
Weed, P. R., Bureau of Reclamation, Casper, Wyo.
Wylie, D. L., Union Pacific Railroad, Omaha, Nebr.

7. South West

Clark, C. C., Jr., Southwestern Gas & Elec. Co., Marshall, Tex.
Classen, C. R., Union Elec. Co. of Mo., Webster Groves, Mo.
Dignowity, L., Cia. Distribuidora Westinghouse S. A., Mexico City, Mex.
Dodson, T. A., West Texas Utilities Co., Abilene, Tex.
Duff, J. R., Westinghouse Elec. Corp., Dallas, Tex.
Ernhart, C. J., Union Elec. Co. of Mo., Webster Groves, Mo.
Fahrenthold, H. W., Jr., Tin Processing Corp., Texas City, Tex.
Grissom, J., Southern Methodist University, Dallas, Tex.
Hernandez M., G., Cia. Distribuidora Westinghouse S. A., Mexico City, Mex.
Kuehnert, T. J., Sverdrup & Parcel, St. Louis, Mo.
Land, H. L., Westinghouse Elec. Corp., Dallas, Tex.
McClellan, C. Y., Beavers & Lodal, San Antonio, Tex.
Maxwell, J. R., West Texas Utilities Co., Abilene, Tex.
Mercer, C. L., Southwestern Bell Tel. Co., Houston, Tex.
Metz, T. W., Allis-Chalmers Mfg. Co., Dallas, Tex.
Mierow, A. C., Central & South West Operating Committee, Abilene, Tex.
Noblett, C. R., Sabine Towing Co., Inc., Port Arthur, Tex.
Oberhelman, L. E., Standard Oil Co., Sugar Creek, Mo.
Ordonez L., S., Cia. Distribuidora Westinghouse S. A., Mexico City, Mexico.
Parker, R. W., Westinghouse Elec. Corp., Beaumont, Tex.
Parra V., A., Cementos Atoyac, Veracruz, Mexico.
Pearce, H. L., Jr., West Texas Utilities Co., Abilene, Tex.
Ragland, J. R., West Texas Utilities Co., Abilene, Tex.
Tucker, D. D., Bureau of Reclamation, Amarillo, Tex.
Villegas R., M., The Elec. Rate Comm., Mexico City, Mex.
Walker, W. E., Union Elec. Co. of Missouri, Webster Groves, Mo.
Whitehead, M. C., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Wilson, G. P., Southwestern Public Service Co., Amarillo, Tex.

8. Pacific

Becker, A. G., Round Valley Lt. & Pr. Co., Springerville, Ariz.
Brubaker, J. W., North American Aviation, Inc., Los Angeles, Calif.
Canady, C. R., Southern Calif. Edison Co., Ltd., Los Angeles, Calif.
Collins, R. E., Municipal Rwy. Public Utilities Comm., San Francisco, Calif.
Duffield, R. J., So. Calif. Tel. Co., Los Angeles, Calif.
Gillum, F. V., So. Calif. Edison Co., Los Angeles, Calif.
Hanson, C. F., So. Calif. Tel. Co., Los Angeles, Calif.
Johnson, L. W., Modesto Irrigation District, Modesto, Calif.
McQuaid, H. L., North American Aviation, Los Angeles, Calif.
Rockholt, L. R. (re-election), A. B. Chance Co., San Francisco, Calif.
Salquist, E. A., So. Calif. Edison Co., Los Angeles, Calif.
Usinger, R. H., General Elec. Co., Oakland, Calif.

9. North West

Burrus, J. H., Jr., Allis-Chalmers Mfg. Co., Portland, Oreg.
Dickson, J. S., P.U.D. No. 1 of Wahkiakum County, Cathlamet, Wash.
Farr, B. H., Westinghouse Elec. Corp., Salt Lake City, Utah.
Huffaker, M. F., Utah Copper Co., Salt Lake City, Utah.
Larson, D. G., Northwestern Elec. Co., Portland, Oreg.
McLennan, J. D., Pacific Tel. & Tel. Co., Portland, Oreg.
Mozena, J. I., Physicians & Hospital Supply Co., Portland, Oreg.
Whittaker, W. S., City of Seattle Dept. of Lighting, Seattle, Wash.

10. Canada

Amos, W. A., Ferranti Elect. Ltd., Toronto, Ont., Canada.
Ballinger, F. S., Hydro-Elec. Pr. Comm., Toronto, Ont., Canada.
Bhargava, R. N., 28 Ross Street, Toronto, Ont., Canada.
Ferguson, D. M., Brompton Pulp & Paper Co., Ltd., East Angus, Que., Canada.
McKim, L. R., Hydro-Elec. Pr. Comm. of Ont., Hamilton, Ont., Canada.
Pile, R. K., Hydro-Elec. Pr. Comm. of Ont., Toronto, Ont., Canada.
Richardson, K. G., Hydro-Elec. Pr. Comm. of Ont., Toronto, Ont., Canada.
Tarrant, E. H., Elec. Pr. Equip. Co. Ltd., Vancouver, B. C., Canada.
Webster, J. A., Elec. Pr. Equipment, Ltd., Vancouver, B. C., Canada.
Woodcroft, J., Hydro-Elec. Pr. Comm., Toronto, Ont., Canada.

Elsewhere

Ahmad, S., B. I. Callenders Cables, Ltd., Bombay, India.
Bate, E. A., Societe D'Electricite et de Mecanique, Ghent, Belgium.
Burns, J. G., State Elec. Comm. of Queensland, Brisbane, Queensland, Australia.
Deodhar, A. P., Ordnance Factory, Ambernath, India.
Hill, L. P., Capt. U.S.A., Office of the Military Attache, London, England.
Labra, A., Peruvian Trading Corp., Lima, Peru.
Moahnty, S. B., Govt. of Orissa, Cuttack, Orissa, India.
Patel, R. P., Central Technical Power Board, Simla, India.
Singh, M. P., Assoc. Elec. Industries (India), Ltd., Calcutta, India.
Smith, W. E., British Thomson-Houston Co., Ltd., Rugby, England.

Total to grade of Associate
United States and Canada, 186
Elsewhere, 10

OF CURRENT INTEREST

ASA Meeting Examines Society's Expanding Program

Speakers at the 28th annual meeting of the American Standards Association held recently in New York, N. Y., were unanimous in regarding the ASA as the guardian of the future health and the past successes of the free enterprise system in the United States.

Standardization is one important answer to the manufacturer's and the consumer's problem of cost control, according to Howard Coonley, chairman of the executive committee of the ASA, who spoke at a luncheon session of the two-day meeting.

Mr. Coonley described how the ASA overcame the financial obstacles in the way of the new position which ASA assumed early in 1945 as the co-ordinating and catalytic agent of producer, distributor, consumer, and government in the development of voluntary American Standards (*EE, Apr '46, p 183*).

PEACETIME FINANCING

"Because of the urgent requirements of such a greatly broadened program," he said, "we had to have immediate and substantial funds. In 1945, we had been spending at the rate of $345,000, $135,000 of which came from government contracts. Naturally, this source of income has been discontinued, and rightfully so. After detailed study, our board of directors estimated that we should require a budget of $560,000 for the first year, and that $200,000 of that should be earmarked as emergency money. That $200,000 now is in the bank. I can report to you today that nearly a quarter of a million dollars in new money has been added to our normal income of $160,000, and another $100,000 is in sight.

"This is conclusive evidence that industry realizes the importance of its stake in standardization. It also supports the conviction that when business has an opportunity to contribute to the well-being of the nation, when it can make a better product at a lower cost, when it sees the opportunity to exercise its responsibilities in a free economic society—that opportunity will not go by default. In the interest of standards as a tool of management, as an efficiency factor in production, and as a protection to consumers, the ASA is prepared to render specialized service for advancing this great movement on its broadened front and to help guide its progress as an important influence in national and international affairs.

"Some 20 new areas in our economy have been brought into the ASA sphere of interest in the past ten months. In the industrial groups, are the aircraft manufacturers, aluminum producers, the boiler companies, chemicals, foundries, instrument makers, new sections of the nonferrous metals industry, office equipment, and air conditioning. We have stirred the interest of the food companies, soap producers, retail groups, the advertisers, and others who are in direct contact with the ultimate consumer, whose representatives are looking increasingly to ASA for guidance in the development of consumer standards. These groups are being asked to carry their fair share of the over-all load on a *quid pro quo* basis. It is our hope that they will do so.

"Fully as important as enlisting financial support from new groups, is bringing to them an appreciation of the leading role standards have played in our economic development. Time and time again I find a complete misconception of what standardization is. Many executives still think of it as a form of regimentation, a curtailment of individuality in product design. When they realize this is not true, arguments against standards disappear. There is not an executive in the country today who is not seeking to cut costs in the face of rising levels of prices and wages, and standards are an answer to that problem which is gaining increasing recognition.

"When I was persuaded to assume the responsibility of guiding the ASA through a reorganization, it was necessary to find an associate to assist me in my present duties and to carry on when I had completed my assignment. It was my extreme good fortune to persuade Donald Armstrong to join me on his retirement from a distinguished Army career. As commandant of the Industrial College of the Armed Forces, chief of the Chicago Ordnance District, and chief of the Tank Automotive Center at Detroit during the war years, General Armstrong's experience has given him a background of intimate contact with industrial problems relating to standards. Standardization was one of the most essential elements in the prewar plans of the War Department. Since that time he has played a leading part in advancing the standards movement in industrial and military circles."

The growing cross section of American industrial, governmental, and consumer groups represented in the ASA was hailed by H. B. Bryans (F '18) retiring ASA president, as "ample proof that standardization is not just a means whereby industry can make more profits—though it certainly contributes to it very decidedly—but is also one of the important aids to the economic and social progress of our country."

Mr. Bryans mentioned that with the recent affiliation of the Society of Motion Picture Engineers, the Heating, Piping, and Air Conditioning Contractors Association, the National Paint, Varnish, and Lacquer Association, and the Screw Industry Standards Committee, which became member-bodies, and the Asbestos Cement Products Association and the Compressed Gas Manufacturers Association, which became associate members, the present ASA membership comprises 58 member-bodies, 38 associate members, and about 2,000 company members.

Carrying on where Mr. Coonley had left off, Mr. Bryans revealed how the additional funds available to ASA had been reflected in an extension of its services. Through additions to the staff and at the request of sponsors and officers of sectional committees, the members of the staff now are serving as secretaries of 45 committees.

This procedure was recommended by the planning committee of the Standards Council as a result of its studies on ways and means of speeding up ASA operations.

"The increase in staff facilities also has made it possible for headquarters to give better service direct to members," Mr. Bryans said. The library facilities have been enlarged and improved. This library, containing more than 20,000 standards, domestic and foreign, plus other technical information relating to standardization, is available for use by all ASA members. As new material is received, it will be analyzed and reports concerning it will be forwarded to interested members and sectional committees.

Among the objects of the ASA as listed in its constitution are "the promotion of the knowledge and use of American Standards and promotion of standardization as a means of advancing the national economy." This obligation has been met in two important ways during the past year, according to Mr. Bryans.

"Mr. Coonley and General Armstrong traveled the country, literally from coast to coast, discussing and explaining the meaning and usefulness of national standardization to industrial, business, and financial executives; the heads of retail and other groups; and consumer groups. Never before has the story of the fundamental importance of standards to the country been put before so wide and important an audience.

"At the same time the staff organization of the ASA has been revised to tell the public, through the newspapers, the technical and trade press, the radio, and the ASA magazine, *Industrial Standardization*, the full story of standards as it develops from day to day as news, or as it needs to be told from time to time in special publications, pamphlets, and other literature.

FUTURE STANDARDS

"Years of discussion on the desirability of simplifying and unifying the size and construction of office furniture, filing cabinets, and other types of office equipment have borne fruit. The first step on a national scale to bring this thinking together in one place came recently when the National Office Management Association requested ASA to initiate a project on standardization of office equipment and supplies. Such a project is a continuing one and never will be finished. It represents an undertaking of considerable magnitude for ASA, but it is an opportunity for service on a large scale.

"Another project is the one recently suggested by the Optical Society of America in the general field of optics. This proposal takes us to the scientific field of the telescope, binocular, surveying instrument, microscope, spectroscope, photometer, colorimeter, and ophthalmic instrument. It will discuss human vision or, as the Optical Society puts it, the psychophysics of vision. It is planned that subcommittees will be appointed to handle such matters as: nomenclature, definitions, symbols; sources of optical energy; filters and polarizing sheet materials; mirrors, prisms, and lenses; mountings; color measurements; vision; spectrographic equipment; general optical instruments.

Mr. Bryans reported that the work of the ASA in the consumer goods field which had been interrupted by the war is being resumed rapidly under the guidance of the Association's Advisory Committee for Ultimate Consumer Goods, and other over-all correlating committees of the ASA.

"The ASA has taken two important steps in its own organization to hasten the progress of such work," he said. "It has filled three posts on its board of directors with representatives thoroughly familiar with consumer problems, and it has created a separate division with its own engineers and technicians in the ASA staff.

"The first is Mrs. Guy Moffett, who represents two important groups of ultimate consumers, the American Association of University Women, and the American Home Economics Association. Max Gertz, vice-president and merchandise manager of B. Gertz, Inc., long connected with ASA work through the National Retail Dry Goods Association, will represent the distributor view on the board. R. Oakley Kennedy, until recently vice-president of Cluett Peabody and Company, will reflect the point of view of the manufacturer of consumer goods."

MODERNIZED PROCEDURE

Further progress in streamlining ASA procedures has been made during the past year, he disclosed.

"Formerly one of the main sources of delay in our procedure was the length of time necessary for the closing of the letter ballots of the Standards Council. This became more acute as the size of the Council increased.

"It was decided finally to place more authority in industry-correlating committees which have been organized by the Council, so that those groups most directly concerned could take final action subject to review by a small group of councilors to be known as a board of review. Through this arrangement the letter ballot of the Standards Council would be eliminated except in cases of appeal from the decisions of correlating committees. The Council retains its full rights and powers and can take action at any time deemed appropriate. These changes in operations required changes in the constitution and bylaws. The desired change in the constitution as developed by the council and approved by the board of directors is before the member-bodies for action. Not all the member-bodies have as yet responded to the ballot, but in view of the unanimous support in the ballots received to date, it is safe to prophesy that these new procedures will become effective by the beginning of the new year."

In closing Mr. Bryans paid tribute to the many people serving on the technical committees of the various member-bodies as the backbone of the standardization movement.

SALVAGING WAR STANDARDS

A review of the effective conversion of the Standards Council from wartime to peacetime problems during the past year was presented by Cyril Ainsworth, technical director and assistant secretary of ASA. The association accomplished the dual task of reactivating its prewar work and of salvaging as much as possible of the technical work which had gone into war-emergency projects.

The ASA procedure under which the emergency war standards were developed provided that, following the cessation of hostilities, all of these standards should be reviewed by ASA correlating committees for the purpose of determining the need for revision, discontinuance, or reapproval of American Standards for peacetime use.

"To date this reviewing procedure has resulted in reaffirmation of 15 standards leaving 138 still to be disposed of," Mr. Ainsworth stated. "Ninety-six of the remaining wartime standards already are under review by committees, but have not yet reached the approval stage. Others will be placed under review as rapidly as possible.

"New regular standards approved in the past year number 31, and revised regular standards approved number 13, making a total of 44. Last year 22 new regular standards were approved, and 21 revised regular standards were adopted. Thus while the total of all standards in the past year numbers 53 against 87 in the previous year, the difference is more than accounted for by the fact that only 9 war standards fall into the current accounting compared with 44 in the preceding year."

In discussing particular projects, Mr. Ainsworth said: "It is doubtful if any standard approved by ASA is as far reaching in its application and affects the living of so many people as the 'National Electrical Code.' This code was developed under the leadership of the National Fire Protection Association by its electrical code committee, which is an ASA-approved sectional committee.

ELECTRICAL CODE

"The 'National Electrical Code' governs the installation of electric wiring, switches, outlets, and other devices in practically all industrial and business buildings and homes in the United States using electricity as a source of power, heat, or light.

"The last prewar edition of this code was approved in 1940. Many emergency requirements were established during the war, but the new edition approved a few weeks ago brings to the electrical industry, governmental agencies, insurance groups, and the general public up-to-date requirements designed to insure that electricity can be used with a minimum exposure to possible hazards of fire and bodily injury."

As an ASA contribution to the current need for new building construction, Mr. Ainsworth referred to the new American Standard for Modular Sizes of Masonry Units recently approved, coupled with the two standards approved late in 1945—"Basis for the Co-ordination of Dimensions of Building Materials and Equipment," and "Basis for Co-ordination of Masonry," provide the building industry and architect with some of the tools. The project under which these standards have been developed is a continuing one.

"Accident prevention is another matter of great importance of the economic and social progress to the country," he said. "It will continue to be of interest so long as in one classification alone—industry—17,500 workers are killed each year, 1,800,000 are injured, and there is an over-all yearly economic loss of $2,350,000,000.

"It will be remembered that it was the safety standardization program that brought the trade associations and the governmental agencies into the national standardization program side by side with the technical societies. One hundred fifty-two standards in the field of accident prevention have been approved by ASA.

X-RAY SAFETY

"The tremendous expansion in the industrial use of the X ray during the war made it necessary that steps be taken to advise both employer and employee as to the hazards involved, if impairment of health and bodily injury on a large scale were to be avoided. One of the important avenues chosen for such a program was the development of a standard covering the construction, installation, and use of the X ray. This standard was developed under the war procedure and was completed early this year. Action already has been taken to have the standard placed in the hands of a peacetime committee operating under the leadership of the National Bureau of Standards as sponsor. The technical contribution of the bureau to the development of this standard and other information regarding the X ray has been outstanding."

THE CONSUMER'S STANDARD

Mrs. Guy Moffett, new member of the ASA board of directors, listed six questions which, she said, the average consumer expected an adequate standard to answer. These were: "How much are we getting at a given price? How safe is the product? What is the size and fit? What does the name or descriptive adjective mean? What is the article's relative worth? Is this article worth anything at all?"

Even the best standards for consumer goods will not function as a guide, Mrs. Moffett added, unless they are stated in terms understandable to a literate person. She declared that the American Standards for coal and gas ranges exemplified good standards that were too highly technical for the average consumer to profit from them. She praised the British standards on building materials and structures as ideal consumer standards "expressed in clear, simple language with a minimum of technical jargon and no sacrifice of technical competence."

The advantages accruing to industry from standardization were expressed forcibly by Ephraim Freedman, director of the bureau of standards of R. H. Macy and Company, New York, N. Y., and member of the Policy Committee on Standards.

"Imagine some four hundred thousand items, each one of which is made by industry for ultimate consumer use," Mr. Freedman said. Each of these articles can be a messenger of good-will or of ill-will, depending upon whether it represents value in terms of quality, performance, and durability. Each of these articles should be a bid for the public's support of free enterprise. That these articles do not always warrant that support is discovered over the retail counter by the doughboy of industry—the retailer.

"Where standards are in existence, a means for communicating pertinent information regarding commodities becomes available or should be made available to consumers. Consumers receiving such information can buy more intelligently, consume more wisely, increase the buying power of their spending dollar. All of which adds up to an increase in the economic well-being of the American public and an increase in good will to free enterprise."

College Research Association. Election of the Harvard University Graduate School of Engineering and the Rhode Island State College Engineering Experiment Station to active membership in the Engineering College Research Association has been announced. This brings the active membership of the association to 71 research institutions, according to Dean F. M. Dawson of the State University of Iowa, association president.

ECPD Announces Officers; Reports on Year's Accomplishments

Appointment of an engineering member of a committee to advise the United States Commissioner of Education, accrediting of the first technical school curriculums, and expansion of the field served by the Pre-Engineering Inventory were chief among the accomplishments of the Engineers' Council for Professional Development mentioned by Chairman Everett S. Lee (F'30) in his report to the council at the 14th annual meeting held recently in New York, N. Y.

More detailed reports on the year's activities were presented by the chairmen of ECPD standing committees on student selection and guidance, engineering schools, professional training, and professional recognition; and election of officers for 1946–47 was announced.

Officers elected are:

Chairman—James W. Parker, president, Detroit (Mich.) Edison Company.

Vice-Chairman—T. T. Read, professor of mining, Columbia University, New York.

Secretary—H. H. Henline (F '43) secretary, AIEE.

Assistant Secretary—A. B. Parsons, secretary, American Institute of Mining and Metallurgical Engineers, New York.

Chairman, Committee on Student Selection and Guidance—Carl J. Eckhardt, superintendent of utilities, University of Texas, Austin.

Chairman, Committee on Engineering Schools—D. B. Prentice, president, Rose Polytechnic Institute, Terre Haute, Ind.

Chairman, Committee on Professional Training—C. A. Pohl, consulting engineer, New York.

Chairman, Committee on Professional Recognition—N. W. Dougherty, dean of engineering, University of Tennessee, Knoxville.

Chairman, Committee on Information—G. Ross Henninger (F '43) editor, AIEE.

COMMITTEE ON PROFESSIONAL RECOGNITION

Ways and means of attaining professional recognition were detailed in the report of Dean N. W. Dougherty in which a plea was made "to all engineers for greater participation in civil and political fields." He stated that in addition to activity in community gatherings the power of the press must not be overlooked. "Excellent books," he said, "have been written during the last few years on the work of the engineer. Unfortunately, the book-reading public is relatively small in number as compared with those who buy magazines. This field has been neglected by us in late years." To encourage the preparation of articles with popular appeal for usch magazines as the *Saturday Evening Post* and *Readers' Digest*, Dean Dougherty suggested "an annual competition sponsored by ECPD, for the ten best papers popularizing the specific work of the author, of a type acceptable to the editors of the national magazines with large circulations." As prototypes of the sort of articles wanted, Dean Dougherty mentioned "The World's Greatest Aquaduct" by Alfred D. Flynn, published in the *Century Magazine* in 1909, and "All Figured Out" in *Harper's* for October 1936.

"Another popularizing medium is the screen," he continued. "Too often the lay public thinks only of the professional engineer as the builder of bridges and skyscrapers. Could we not write specifications for a series of ten-minute films illustrating phases of the making of everyday necessities, each concluding 'March of Time'-wise with 'The luxuries of yesterday have become the necessities of today and are provided by that service-rendering group, the engineers?' "

Professor Dougherty characterized unity among engineers as basic to any widespread recognition from the general public. He deplored the tendency toward fragmentation of engineering knowledge which is started even in the engineering schools. He found support for this opinion among spokesmen for educators and for industry, quoting the comments of the late A. R. Stevenson, Jr., of the General Electric Company:

> At the General Electric Company, for more than 20 years, we have been making mechanical engineers out of electricals, and electricals out of mechanicals. We ignore what a man's original degree may have been, and we have electrical graduates designing gas turbines for jet propulsion and mechanical graduates designing transformers . . . We think it is a mistake to compartmentalize knowledge. We would like to see professors of thermodynamics fail to mention the "first law of thermodynamics" and refer to it as the law of the conservation of energy.

The most effective field for gaining greater public acceptance of engineers as professional men is that of civic and political endeavor, Dean Dougherty declared; and for the willing but inexperienced who might wonder where to start he suggested the reading of "How to Become a Responsible Citizen" by Roy V. and Eliza G. Wright, published in 1938 by the Association Press in New York.

He also suggested church groups as a point of entry into neighborhood affairs, where the influence of the engineering mind often is needed.

Disintegrating forces enumerated by Dean Dougherty as those to be guarded against were jealousy in the border-line fields, against the evils of which the jurisdictional disputes of unions stand as ample warning, and the problem of collective bargaining. If professional consciousness is to be maintained among young engineers, an adequate substitute for his absorption into nonprofessional unions must be found.

"If engineers are going to create the atmosphere and climate for professionals to grow, they must see to it that the climate has a background of compensation comparable with training and future responsibility," he said. He quoted W. E. Wickenden (F' 39) and H. E. Nold of Ohio State University in support of this view.

Recommendations of this committee were:

1. More rapid action toward developing a uniform code of ethics.

2. Uniform membership requirements and uniform nomenclature for grades of membership in the technical engineering societies.

3. Producing a permanent and popular record of engineering achievements during the war.

4. That technical societies through their publications emphasize the professional phases of engineering.

5. That constituent bodies should use their influence to prevent further multiplication of engineering specialties.

STUDENT SELECTION AND GUIDANCE

Carl J. Eckhardt Jr., University of Texas, reporting for the committee, mentioned the widespread use of a screening test for pre-engineering students. Called the "Pre-Engineering Inventory," its purpose is to "select engineering students with the expectation which accompanies the selection of materials with which engineers deal." During the 1945–46 academic year, 32 institutions used the inventory for 12,300 students.

A second screening is proposed with the preparation of "Sophomore Achievement Examinations." These will "serve to reassure those students who should continue their engineering studies." Usefulness of the screenings to the colleges in sampling the needs of their students is quite evident. Proposed, but not yet prepared, are "Senior Examinations" to provide information for graduating students, their educators, and prospective employers. Money for these tests has been made available by The Carnegie Corporation of New York and by the Carnegie Foundation for the Advancement of Teaching, the American Society for Engineering Education, and ECPD.

In the course of the period during which the inventory has been developed, it has been administered to more than 36,000 persons. The researches have been extended to include 35 colleges. After three years of experimentation and refinement all colleges of engineering having curriculums accredited by ECPD which are not yet participating in the program have been invited to participate. Some 14 additional institutions have joined in the project since the invitation was extended.

For the guidance of students aspiring to be engineers, a booklet "Engineering as a Career" was developed by the late Dean Emeritus R. L. Sackett of Pennsylvania State College and others. To date over 70,000 copies have been distributed through colleges, high schools, professional societies, book stores, and commercial agencies.

The major effort of the committee in its guidance program for the past year has been to see that copies of "Engineering as a Career," were placed in the hands of aspiring engineers, as well as in the possession of teachers and parents of such students. In the course of the year emphasis was placed upon a distribution of these booklets among principals of high schools in communities having a population of 5,000 inhabitants or more and among veterans returning to scholastic pursuits. The total number of copies distributed approximated 23,000. Principal changes changes in the pattern of distribution for the year were:

1. The number of copies distributed gratuitously was reduced.

2. No sales were made to military agencies.

3. Colleges were encouraged to use this publication in greater numbers.

As the committee still believes that the number reaching high school students still is too small, it has established a new plan for working through the local sections of the various professional engineering organizations. The following advantages are offered by this plan:

1. Professional engineers are better qualified to offer guidance to such prospective engineering students.

2. Interest among high school students in reaching proper conclusions can be stimulated greatly by helpfulness on the part of persons who are not teachers, but are practicing engineers.

3. Program of this character will do much to establish fellow feeling between high school teachers and the professional engineers within communities.

EXAMINATION OF CURRICULUM RECOMMENDED

At an early date, re-examination of the curriculums of all those engineering schools which already have had curriculums accredited, was recommended by the committee on engineering schools. A questionnaire was sent to all such institutions to determine their readiness for such re-examination. Most institutions have replied that, because of difficulties encountered in returning to "normal" after the war years, they would prefer that such inspection be postponed until 1947–48.

New inspections were at a minimum during the last year. The curriculum in chemical engineering, at the Agricultural and Mechanical College of Texas, was accredited at the annual meeting.

The accrediting of technical institutes is well under way by a committee headed by Dean H. P. Hammond of Pennsylvania State College. The following curriculums at technical institutes were accredited:

Wentworth Institute, Boston, Mass.
Architectural construction.
Electrical construction.
Machine construction and tool design.
Steam and diesel engineering.

Bliss Electrical School, Washington, D. C.
Fundamentals of industrial electrical engineering.

Capitol Engineering Institute, Washington, D. C.
Practical radio engineering—Residence course.
Practical radio engineering—Correspondence course.

The committee also recommended a program of accrediting graduate curricula.

However, Dean Hammond expressed disappointment in the relatively small number of technical institutes requesting inspection and accrediting. Their response has been much slower than that of the colleges when the program first was initiated.

D. B. Prentice, president of Rose Polytechnic Institute, chairman of the committee, reported that out of 167 degree-granting institutions in the United States, 133 now have one or more curriculums accredited by ECPD, with a total of 580 curriculums accredited in major and specialized fields.

The committee has formed a subcommittee on student development which has the function of studying those factors which should be considered in connection with the Pre-Engineering Inventory and its accompanying achievement tests, as they relate to problems affecting standards of instruction and educational procedures in engineering schools. It also expects to explore the possibilities of inventorying the personality factors which might complement the work on intellectual abilities.

It was reported that the "Guide to the Evaluation of Educational Experiences in the Armed Services," is being used widely by colleges and universities, and two editions of more than 75,000 copies have been printed. This guide was prepared by the American Council on Education, and ECPD contributed to the initial cost of the project.

Doctor Prentice read excerpts of a letter received from Dean S. S. Steinberg of the University of Maryland, on the subject of accrediting schools in Latin America. The excerpts follow:

> In the course of my tour last summer I visited 25 engineering schools located in 12 of the other American republics. The schools inspected included many types and among them were the most important ones.
>
> Several of the more progressive university presidents and engineering deans are anxious for ECPD to inaugurate a program of accrediting of their curriculums. They realize that, though the schools may not be able immediately to meet ECPD standards for accrediting, they are anxious for an inspection of their facilities and an evaluation which will apprise them of their needs to achieve recognition.
>
> As discussed previously, the procedure that might be followed would be for a small committee of educators and engineers to visit the schools after preliminary inquiry had revealed which desired inspection and necessary arrangements had been made. I believe that the schools requesting the visit would defray proportionately the costs involved.
>
> All the schools asking for inspection would not necessarily have to be visited on one trip. I would suggest a Caribbean circuit which might include Cuba, Venezuela, Colombia, and Mexico; then a South American circuit to include Peru, Chile, Argentina, Uraguay, and Brazil.

Doctor Prentice reported that ECPD had been asked to name a representative on the Citizens Federal Committee on Education, an advisory committee to the Commissioner of Education. This is the first such recognition of engineering education. Henry H. Armsby was appointed as a specialist in engineering education to serve as liaison officer between the Office of Education and the engineering colleges.

A survey of engineering salaries was conducted, at the request of a group of deans of engineering, among 200 companies on May 1. The results are in Table I. Doctor Prentice deplored the lack of recognition of advanced academic work which the survey indicated.

Recommendations made to the council by the committee included one for an exchange among the engineering schools of young graduates who are being employed to relieve the shortage of instructors; the adoption of a method of indicating accredited co-operative curriculums; and the advancement of engineering shopwork programs.

COMMITTEE ON PROFESSIONAL TRAINING

To assist the engineer in his professional development after graduation, the com-

Table I. Survey of Engineers' Salaries

	Salaries Per Month		
	Low	Average	High
For inexperienced graduates (68 returns)	$150	$206	$261
For inexperienced graduates with master's degrees (56 returns)	150	229	288
For graduates with three years' of satisfactory experience:			
Bachelor's degree (53 returns)	200	275	350
Master's degree (44 returns)	225	303	450
For graduates with five years of satisfactory experience:			
Bachelor's degree (48 returns)	250	328	450
Master's degree (39 returns)	250	356	462
For graduates with doctor's degrees (28 returns)	225	326	500

mittee on professional training has prepared and circulated a number of aids. In his report, Doctor C. A. Pohl, New York consulting engineer, listed the following: reading lists and bibliographies, personal appraisal blanks, lists of college extension programs, lists of appropriate articles, and reprints of certain pertinent articles. Dr. Pohl's committee urged closer co-operation between practicing engineers and younger members of the profession, to the end that encouragement and direction be given to the professional development of those entering the engineering profession.

Doctor Pohl placed a major part of the responsibility for professional development of young engineers on the older experienced engineer. He reiterated the question asked by the late Professor Charles F. Scott:

> Are we living up to our own obligations as engineers if we neglect or refuse to share in the training of those who are to succeed us in the organized work of our profession?

He enthusiastically endorsed the "Manual for the Professional Orientation of Engineering Students" by C. J. Eckhardt as the best ever written for the purpose of giving the student a proper concept of engineering and the qualities of an engineer.

COMMITTEE ON EMPLOYMENT CONDITIONS

The committee on employment conditions for engineers reported that during the year its chairman, V. T. Boughton, associate editor, *Engineering News Record*, had studied the activities of the Committee on the Economic Status of the Engineer of the Engineers' Joint Council, which is surveying the compensation of the whole engineering profession. In view of the progress being made by EJC and the doubtful value of duplicating the effort, Mr. Boughton's committee recommended that his group be discharged and that ECPD request permission to continue to have an observer sit in at meetings of the EJC committee.

The committee presented the following review of recent Government attitudes in collective bargaining cases.

Labor Board Decisions. A review of decisions of the National Labor Relations Board with respect to engineers adds support to the conclusion that the present board considers that engineers, chemists, and other professional men have interests apart from those of the general run of employees in any company. In every instance where engineers have sought separate representation, it has been granted, although not always in just the form sought by the engineers. Such separate representation will not be granted automatically; the professional men must demonstrate to the board that they want separate representation and are organized to make it effective.

The board has not given support to the the proposal put forward by the American Society of Civil Engineers and others that the decision as to who is and who is not to be included in such bargaining groups for engineers should be basedon the individual's training and professional qualifications. The board insists that the grouping be done on a functional basis. It will not put a man with an engineering degree who is doing only subprofessional work in with the men who are functioning as engineers just because he has an engineering degree. If the subprofessional men are in a separate bargaining group, he is put in that. On the other hand, the board may group all subprofessional men and some clerical workers with the professional men if such grouping appears logical to the board.

The Status of Engineers in Canada. In Canada, the long uncertainty as to the relation of engineers to Dominion and Provincial labor laws was resolved largely by two recent decisions of the Wartime Labour Relations Board, one relating to engineering employees of the Toronto Hydro-Electric System, and one with respect to engineers employed in the eastern area of the Bell Telephone Company of Canada.

As noted in earlier reports of this committee, following the promulgation of an Order in Council setting up the National Wartime Labour Relations Board, the principal engineering organization in Canada sought and obtained temporary exemption from the provisions of that act in order to give them time to determine just what status they would prefer to have under the act. Subsequently, they sought unsuccessfully to establish an entirely independent labor board to deal with professional men.

In its first two decisions with respect to engineers, the board made it clear that in its opinion professional employees should come under the provisions of the Dominion and Provincial labor laws, also that as a general rule they should be segregated from other employees for collective bargaining purposes. On the question of classifying employees on the basis of training or function, the Canadian board agrees with the board in the United States that classification should be on a functional basis.

The Canadian board appears to have leaned over backward in the Bell Telephone case in the matter of classifying men as "employed in a confidential capacity" or as having the power to hire and fire, and so excluded from the provisions of the Dominion labor law. This was disappointing to the Quebec Federation of Professional Employees as that organization hoped to be able to represent all but the top administrative men in the company's engineering department. On the other hand, the board insisted that the subprofessionals employed in an engineering capacity be included in the collective bargaining group.

A somewhat similar situation developed in the United States, with respect to engineering employees of the Radio Corporation of America, Camden, N. J. There, the NLRB classified many engineers as supervisory who, in the opinion of the Association of Professional Engineering Personnel at the RCA plant, can not legitimately be so classified.

Few Strikes Affecting Engineers. Engineers have been involved in few strikes during the year. The one that received the most publicity was in the design division of the Stone and Webster Engineering Corporation, Boston, Mass., where an attempt was made to get the building trades unions on Stone and Webster jobs to go out in sympathy with the engineers. The union involved was a local of the International Federation of Technical Engineers and Draftsmen's unions (American Federation of Labor). The men were out some weeks before a settlement was reached which appears to have been somewhat of a draw.

As noted in the semiannual report of this committee, the Federation of Architects, Engineers, Chemists and Technicians, which has been the active Congress of Industrial Organizations union in the engineering field for bout 15 years, now has become the Technical and Scientific Division of the Office and Professional Workers of America, another CIO affiliate.

A drive is now on to organize all employees at the Government's atomic bomb plant at Oak Ridge, Tenn., which presumably will result in an effort to include the engineers in a CIO or AFL union. It was at that plant during its construction that an organization set up under ASCE auspices stepped in to help the engineers keep from being absorbed by an AFL union.

Independent Organizations. In the Los Angeles region, the Engineers and Architects Association, which started out as the Engineers and Architects Association of Southern California, has expanded so that it now has seven chapters, including one in the San Francisco Bay area.

In the Far Western States numerous independent groups of professional engineering employees have been organized, most of them under the sponsorship originally of the American Society of Civil Engineers. Some of those have been recognized formally by the National Labor Relations Board as the appropriate collective bargaining agency. Thus the right of engineers to set up collective bargaining groups independent of the AFL or the CIO seems to be definitely established.

COMMITTEE ON INFORMATION

The preparation of a list of all engineering societies in the United States and Canada was an accomplishment reported by the committee on information. Sydney Wilmot, chairman of the committee, reported that 237 organizations had been listed with classification according to "grade of membership subject to admission requirements." This committee also reported the pending publication of the "Fifteenth Anniversary Booklet of ECPD."

This booklet has been prepared for a dual purpose—information on the activities of ECPD and the stimulation of contributions to a professional development research fund to be administered by the ways and means committee. This program will be under the direction of a special subcommittee headed by R. L. Goetzenberger, vice-president of Minneapolis-Honeywell Regulator Company. This subcommittee reported that "fund-raising is our primary objective. . . to defray the expense of" a professional development fund supervised by ECPD. To give meaning to the fund-raising campaign, the committee called for "a listing of projects which require investigations within its scope, and for the accomplishment of which funds are necessary."

COMMITTEE ON PRINCIPLES OF ENGINEERING ETHICS

The committee reported that under the chairmanship of D. C. Jackson (F '12) professor emeritus of electrical engineering at Massachusetts Institute of Technology, the committee reported the development of a universal "Canon of Ethics" for all engineers. The code has been prepared after extensive study of the respective codes of participating societies, and the draft has been approved by a number of constituent organizations. The final code is expected to be issued soon.

Cloud Turned Into Snow. In the first outdoor experiment with a laboratory method of turning supercooled moisture into snow, scientists of the General Electric Company recently were successful in transforming a cloud three miles long into snow. The experiment made in western Massachusetts was conducted from an airplane. From a 14,000-foot level, the snow fell an estimated 3,000 feet, but because of the dry condition of the atmosphere beneath the cloud, the snow evaporated before reaching the ground. To produce the snow six pounds of dry-ice pellets were dispensed throughout the length of the 3-mile cloud. Within two minutes after the dry ice was dropped, a radical modification of the cloud took place, and observers more than 50 miles away saw streamers of snow pour from the base of the cloud. Success of the experiments confirms the hypothesis that natural clouds do not contain ice particles, as often has been supposed, but droplets of supercooled water. Possibilities for use of the method to clear away clouds and to produce a ground cover for winter sports or as an irrigation aid are being studied.

Electric Plant in China. The Chinese government plans to build a $35,000,000 electrical manufacturing plant. This plant will produce central station and other electric equipment under American patents. The Chinese government is to be assisted in this by Westinghouse Electric International Company which will design the proposed plant, provide production processes, specify machinery, and train personnel. The Westinghouse company will receive a lump sum payment, for patents and technical services, during the first ten years of the plant's operation and royalty payments during the second ten years but will hold no financial interest. The plant will be equipped with machine tools costing about $15,000,000.

Telecommunications Conference a Probability in U. S. in 1947

With Britain the sole dissident, the delegations of the United States, Russia, China, and France to the recent Moscow Telecommunications Conference recommended that the United States be asked to invite members of the International Telecommunications Union to a plenipotentiary conference in July 1947. The request would be made through the United Nations Economic and Social Council.

British opposition was based on the grounds that holding the conference in the United States would be a violation of the existing convention. Britain suggested that the countries involved await the conclusion of consultations now going on between the Swiss Government and members of the International Telecommunications Union concerning a world conference in Switzerland.

The 1947 conference will meet to accept a new convention on telecommunications and to reorganize the International Telecommunications Union. One important recommendation made at Moscow proposed the establishment of an international board for the registration of frequencies. The board would consist of representatives of various countries who had the necessary technical qualifications and extensive practical experience.

The conference also recommended that the International Telecommunications Union be reorganized and "enter into relationship" with the United Nations.

It was stated too that the questions of improvement of the organization of radio communications and the reallocation of radio frequencies for maritime, aeronautical, and long distance broadcasting were "particularly urgent problems."

Sanford Moss Dies. Doctor Sanford Alexander Moss, engineer and inventor who developed the turbosupercharger for airplane and automobile engines, died November 10, in Lynn, Mass., at the age of 74. Born in San Francisco, Calif., he was graduated from the University of California in 1896 and received his master of science degree in 1900. He went to Cornell University, Ithaca, N. Y., as graduate student and instructor and earned his doctor of philosophy degree in 1900 with a thesis on the gas turbine. Immediately afterwards he joined the General Electric Company, West Lynn, Mass. He retired in 1937 but returned to the company when war became imminent to work on refining the turbosupercharger. Doctor Moss first conceived the idea of the turbosupercharger which was to make possible the height, speed, and range of modern airplanes, when he was 17. He had perfected it by the end of World War I at the request of the National Advisory Committee for Aeronautics, but with the coming of peace the airplane manufacturers lost interest, and a few were installed in racing automobiles. In all, Doctor Moss is credited with 47 patents. He was awarded the Collier Aviation Trophy in 1940 for "outstanding success in high-altitude flying by the development of the turbosupercharger," the Sylvanus Albert Reed Award of the Institute of Aeronautical Sciences, the New England award of the Engineering Societies of New England, the Holley Medal of the American Society of Mechanical Engineers, and the Howard N. Potts Gold Medal of the Franklin Institute. He received the honorary degree of doctor of laws from the University of California in 1943. Doctor Moss was a member of the AIEE from 1912 to 1935. He was a member of the International Electrotechnical Commission, the American Society of Mechanical Engineers, and the Institute of Aeronautical Sciences.

High-Frequency Wave Measurement. Development of the water calorimeter, an exceedingly accurate instrument for the measurement of high frequency waves, was announced recently by Doctor Ernst Weber (F '34) head of the Microwave Institute of the Polytechnic Institute of Brooklyn. The water calorimeter was evolved toward the end of 1945. By determining the temperature rise of water through which high frequency waves are passed, the calorimeter can measure the power of microwaves. Formulas have been worked out which give the power of the waves in relation to the temperature rise of the water. The instrument is expected to improve the design of high frequency equipment because it will be known for certain whether the waves will reach 100 miles or only 90 miles, according to Doctor Weber. Previously used instruments sometimes erred by as much as 50 per cent. Several of the instruments have been delivered to the Army Air Forces, and others are scheduled for delivery to Government laboratories.

ISO Organized; Elects Coonley President

Howard Coonley, chairman of the executive committee of the American Standards Association has been elected president of the new International Organization for Standardization, the formation of which has been completed by delegates from 25 nations meeting in London, England.

Gustave L. Gerard, staff president of the Belgian Standards Association, will be vice-president of the new organization, to be known informally as ISO. Headquarters will be set up soon in Geneva, Switzerland, which was chosen in a close final ballot of 12 to 11 over Montreal, Canada.

Formation of the new ISO consolidates into a single organization the work of the old International Federation of National Standardizing Associations and that of the United Nations Standards Co-ordinating Committee. The International Electrotechnical Commission is expected to be ISO's electrical division.

The members of ISO will be the national standards bodies. Its work will be carried out through technical committees upon which any country may be represented, if it so desires.

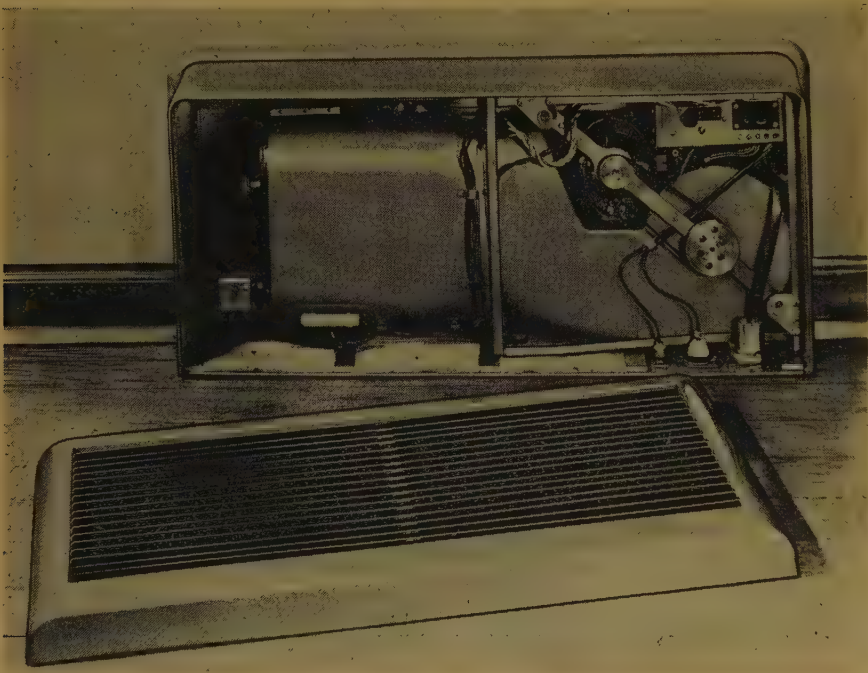
The governing body of ISO will be a council containing representatives from 11 countries. Five of these seats are assigned for a period of five years to China, France, Great Britain, the United States, and the Soviet Union. Others represented initially on the council are Australia, Belgium, Brazil, India, Norway, and Switzerland. The ISO will use three official languages: English, French, and Russian.

The new ISO organization is provisional, and it will be completed formally when its constitution is ratified by 15 national standards bodies.

Represented in ISO's formation were:

Australia, Austria, Belgium, Brazil, Canada, China, Czechoslovakia, Denmark, Finland, France, Italy, India, Mexico, Netherlands, New Zealand, Norway, Palestine, Poland, South Africa, Sweden, Switzerland, United Kingdom, United States of America, Union of Socialist Soviet Republics, Yugoslavia.

Dispersed Units Challenge Central Heating



From experience gained with airplane heaters during the war, the Stewart-Warner Corporation, Indianapolis, Ind., has developed this gas-burning furnace unit which will heat $2\frac{1}{2}$ rooms. The units can be recessed in a wall between two rooms or can be placed on a closet shelf, beneath the floor, in the ceiling, or in the attic. The unit is 14 inches wide, so that it fits readily between studs or joists, is about 30 inches long, and $9\frac{1}{2}$ inches thick. It weighs 70 pounds with a cabinet and 45 without. The unit is noiseless and can be installed in three hours. It is 80 per cent efficient, requiring an input of 31,000 Btu's per hour for an output of 25,000 Btu's. The unit is equipped with a thermostatic control, and, with several units replacing a single furnace, varying zones in the home can be kept at different temperatures. Fuel is burned in a confined, sealed space, which permits small, sealed metal tubes for venting the unit, instead of a chimney. The fire is fed from air outside the house and discharges outside the house. This closed metal path is a protection against fire and asphyxiation. All the safety and performance requirements of the American Gas Association have been met, and, so far as is known, this is the first time that approval has been granted for the use of electric spark ignition in a device of this kind

OTHER SOCIETIES

ASME President Urges Stand on Unionization

With increasing efforts to unionize engineers, the engineering profession no longer can sidestep its responsibilities in the controversial area of collective bargaining, D. Robert Yarnall, president of the American Society of Mechanical Engineers, declared at a recent meeting sponsored by the New York section of the society on the theme "Organization of the Engineering Profession."

Placing better industrial relations in American industry high on the list of responsibilities that must be shouldered by the engineering societies, Mr. Yarnall said, speaking for the ASME, that "a sense of direction is very desirable and is expected by our younger members. They want some organization to turn to now, and if I understand them correctly, they do not want the union kind."

Mr. Yarnall, president and cofounder of the Yarnall-Waring Company, and a member of the City Planning Commission of Philadelphia, Pa., said in part:

"It is true that 'the best men have high scarcity value,' hence they can bargain best as individuals. Men of average or less than average ability certainly have less power in individual bargaining, but does it necessarily follow that their best course for advancement would come through unionism and collective bargaining? This is where good management should provide an adequate personnel policy which will not lose touch with either the best man, the average man, or the subaverage man in their needs and right for advancement. How can we develop better a professional spirit in engineering than by driving home over and over again our conviction that management must assume more responsibility for encouragement, recognition, and advancement (when earned) of all technical men. The potential professional serving his internship in a subprofessional group as a union member in a larger company may gain very useful experience, but let him beware of the limitations of a system which is designed for the average engineer.

"The desire for collective action seems strong among many young engineers in our country. If we were young engineers employed in a large company today, we would be pressed to join with a representative bargaining group, because the unions are doubling their efforts to organize engineers. From what I hear of the experience of young engineers there seems little else that can be done in most circumstances. We understand further that the unions now are willing to accept responsibility for improving the economic status of the engineering personnel."

Mr. Yarnall reminded his audience that the middle-age and older engineer groups are composed largely of executives and managers and chief engineers, who in most cases are responsible for the employment of younger engineers. They look upon the young men as the potential managers and executives of the next generation. Two pertinent questions facing management on this score were posed by Mr. Yarnall:

1. If a young man joins a white-collar union representing engineers and draftsmen, how will the transition period from his classification as a union member and his classification as an executive and/or manager be made?
2. Will not his experience with the union make him more understanding and so more valuable as an executive or as a manager when heavier responsibilities come his way, since apparently collective bargaining is here to stay?

As for the place of the engineering societies, they, he said, "are created for the broad purpose of tabulating, recording, and disseminating engineering knowledge for the good of mankind. They have their social functions, affording opportunities for broadening contacts through professional meetings; they are also creators of codes and standards and ethical practices. Our societies are technical educational institutions of great importance. They are a great deal more than organizations created for the purpose of helping members make more money."

One course of action, Mr. Yarnall said, is suggested by the recent formation of the National Professional Employes Association, composed of engineers, architects, industrial scientists, and similar professional employes. Their purposes are defined "to promote the welfare and professional status of members and the right of professional employes to bargain collectively through agencies of their own choosing. They plan to assist groups to set up independent bargaining units independent of the national unions.

Another plan of procedure mentioned by Mr. Yarnall was that the Founder Societies take immediate action to combat the expansion of labor unions into the engineering field. "This point of view" he said, "would encourage all members to obtain their professional licenses through their state section of the National Society for Professional Engineers. It is claimed that such positive action by all of the Founder Societies would enable the professional engineer to present a united front against the threat of unionization and in defense of the engineer's hard-earned status as a professional man."

Mr. Yarnall referred to the information being collected by the Engineers Joint Council as a step in the direction of the engineering societies assuming their responsibility for defining the position of the engineer in industry. In particular he mentioned the following surveys in which AIEE is co-operating:

1. A survey of the report of earnings of 85,000 engineers, with relation to education, years of practice, and field of specialization, which is to be completed in June 1947.
2. A survey of 2,000 industrial companies to determine company policies pertaining to selection, training, placement, advancement, guidance, and professional activities of graduate engineer employees.
3. A survey of the problem of collective bargaining as it affects or may affect engineers in professional work and in training. The first manual will provide guidance for engineer employees, and is nearly completed.

Future Meetings of Other Societies

American Chemical Society. 111th national meeting, April 14–18, 1947, Atlantic City, N. J. 50th annual meeting, June 16–20, 1947, Atlantic City, N. J.

American Institute of Mining and Metallurgical Engineers. Annual meeting, March 17–22, 1947, New York, N. Y.

American Society for Engineering Education. 55th annual meeting, June 18–21, 1947, Minneapolis, Minn.

American Society for Testing Materials. Spring meeting and committee week, February 24–28, 1947, Philadelphia, Pa.

American Society of Heating and Ventilating Engineers. 53d annual meeting, January 27–30, 1947, Cleveland, Ohio.

Electrical Engineering Exposition. January 27–31, 1947, New York, N. Y.

Institute of Radio Engineers. Annual meeting, March 3–7, 1947, New York, N. Y.

Materials Handling Exposition. January 14–17, 1947, Cleveland, Ohio.

Pacific Chemical Exposition, October 21–28, 1947, San Francisco, Calif.

ASA Officers Elected. Election of a president and vice-president for 1947 was announced at the 28th annual meeting of the American Standards Association in New York, November 22. Frederick R. Lack (M '37) vice-president of the Western Electric Company since 1942 was elected ASA president, and George H. Taber, Jr., executive vice-president of the Sinclair Refining Company, was elected vice-president. In a congratulatory message to Mr. Lack, Secretary of Commerce W. Averell Harriman said, "In the critical years ahead, I envision the ASA federation of some 100 trade, technical, consumer, and governmental bodies as making an outstanding contribution to strengthening our national economy."

AIME Announces 1947 Officers. Results of its election of officers for the coming year recently were announced by the American Institute of Mining and Metallurgical Engineers. Officers for 1947 will be:

President—Clyde E. Williams, director of the Battelle Memorial Institute, Columbus, Ohio.

Vice-Presidents—Andrew Fletcher, vice-president of the St. Joseph Lead Company, New York, N. Y., and Robert W. Thomas, general manager of the Nevada Consolidated Copper Corporation, Ray, Ariz.

Directors—Oliver Bowles, chief of the Nonmetallic Economics Division of the United States Bureau of Mines, Washington, D. C.; Arthur J. Blair, chief geologist of the Tennessee Coal, Iron, and Railroad Company, Birmingham, Ala.; William W. Mein, Sr., president of the Calaveras Cement Company, San Francisco, Calif.; C. V. Millikan, chief production engineer for the Amerada Petroleum Corporation, Tulsa, Okla.; Earle E. Schumacher, chief metallurgist for the Bell Telephone Laboratories, Inc., Murray Hill, N. J.; and John R. Suman, vice-president of the Standard Oil Company of New Jersey, New York, N. Y.

ASA Appoints Service Engineer. The appointment of Eugene Somoff to the newly created post of technical service engineer was announced recently by the American Standards Association. Mr. Somoff, an electrical engineer with experience in the United States and abroad, will collect and supply technical information concerning American standards and those of other countries. During the war he served as a Russian translator for the United States Army.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

The Sign of Reactive Power

To the Editor:

The report of the AIEE Standards committee on "The Sign of Reactive Power" published in the November 1946 issue of *Electrical Engineering*, pages 512–16, invited discussion and comments. Here are mine.

I am in hearty agreement with the recommendation that the previously adopted standard on the sign of reactive power be changed. The practical reasons given in the report, pertaining to the generation, transmission, and consumption of reactive power, are sufficient grounds for the change. However, let me add one more reason for it.

Long ago, when reactance was defined, it was decided that inductive reactance should be positive and capacitive reactance, negative. This seems to be one sign convention about which no one argues.

Later, when susceptance was defined, a choice of its sign had to be made. There were two possibilities, each having some consistency with the convention on reactance.

1. Susceptance could be defined as the real part of admittance, just as reactance is the real part of impedance. This choice would result in capacitive susceptance being positive and inductive susceptance, negative.

2. Inductive susceptance, like inductive reactance, could be considered positive; and capacitive susceptance, like capacitive reactance, considered negative.

The second way was chosen. The convention thus established is still the standard, as may be confirmed by a careful reading of definition 05.20.210 of the "American Standard Definition of Electrical Terms." Not everyone adheres to this standard convention on susceptance; however, there has been no strong movement to change it. (Incidentally the report to which I just referred does not follow the standard convention on sign of susceptance. If it did, the first line of equation 12 would read $Y=G-jB$; the second line of equation 13 would read $B=+X/(R^2+X^2)$; equations 3 and 15 would lead to the same convention on the sign of reactive power, though the last line of equation 16 would not; and several other statements would require alteration.)

Since the standard conventions on signs of reactance and susceptance are consistent in that both are positive when inductive, the only convention on the sign of reactive power that is consistent with those two sign conventions is to make the reactive power consumed by an inductance positive. This consistency would be achieved by the recommended change.

We would then have the simple rule: *Reactance, susceptance, and reactive power associated with inductance are positive.*

Let us urge that the American Standards Association adopt the recommendation.

EDWARD W. KIMBARK (M '35)

(Professor of electrical engineering, Northwestern University, Evanston, Ill.

To the Editor:

Referring to the report entitled "The Sign of Reactive Power" appearing in the November 1946 issue of *Electrical Engineering*, the second advantage given under the topical heading, "Practical Considerations in Selecting the Sign of Reactive Power," states that "rate structures commonly are based on charging for the integrated use of real and inductive power, both considered as positive quantities." I wish to point out that rate structures are based not only upon the integrated use of power, but also upon the demand use; although which is the more common I cannot say. In giving any further publicity to this subject, I believe that this fact should be brought out, although it does not alter essentially the argument in favor of considering inductive reactive power positive.

This correction was pointed out to W. A. Lewis in reviewing the article, but the comment did not reach him early enough to bring about the change. I therefore am forwarding this comment to you in order to correct any inference that rate structures are based only on integrated use.

HOLLIS K. SELS (F '45)

(Transmission and distribution engineer, electric department, Public Service Electric and Gas Company, Newark, N. J.)

To the Editor:

I have read with interest the committee report in *Electrical Engineering* for November 1946 on "The Sign of Reactive Power." I agree that the proposal of the committee is a good one and should be adopted.

However, I hope that I may be pardoned if I suggest that the committee has gone to considerably greater length than necessary to illustrate the dilemma of the sign of reactive power. One can succeed in getting himself confused just as readily, and moreover with striking dispatch, merely by considering a circuit consisting of a single reactive element. Let us look at such a circuit (Figure 1), which has in it nothing but a coil of pure inductive reactance, X, supplied by a voltage, E, which causes a current, I, to flow. The vector diagram (Figure 2) for this circuit is almost the simplest possible, the current, I, being 90 degrees behind the voltage, E.

If we know I and X and wish to calculate E vectorially, we may write

$$E=jXI \tag{1}$$

The j shows that E is 90 degrees ahead of I. We already have all the information we need for dealing with reactive power. The power, which is all reactive in this case, is

$$\begin{aligned} Q&=EI\\ &=jXI^2 \end{aligned} \tag{2}$$

Now, if we know E and X and wish to calculate I vectorially, we may write

$$\begin{aligned} I&=\frac{E}{jX}\\ &=-j\frac{E}{X} \end{aligned} \tag{3}$$

The $-j$ shows us that I is 90 degrees behind E, and the reactive power is

$$\begin{aligned} Q&=EI\\ &=-j\frac{E^2}{X} \end{aligned} \tag{4}$$

All this seems childishly simple, but the trouble is nevertheless at hand. Rushing in where angels should fear to tread, one surely would say that the reactive power for this single circuit element must be the same, whether calculated by equation 2 or equation 4. We can try it and see:

$$\begin{aligned} Q&=jXI^2\\ &=-j\frac{E^2}{X} \end{aligned}$$

from which

$$\begin{aligned} X^2&=-\frac{E^2}{I^2}\\ &=-X^2 \end{aligned}$$

Obviously, we already have our dilemma of the sign of reactive power: Numerical equality but not vectorial equality.

When we ask how such an apparent discrepancy can enter so quickly, the answer must be simply that, when we deal with vectors and phase differences, we must expect apparent inconsistencies as soon as we change our starting point or point of reference. Implicit in all of the reasoning resulting in equations 1 and 2 is the assumption that I is the starting point. When we calculated E we started with I and said that the j in equation 1 showed us that E was 90 degrees ahead of I. The same reference point is maintained in equation 2 where Q is calculated with its phase relation referred to I.

But in equations 3 and 4, E has become the reference, unconsciously perhaps but none the less truly. We start with E, then we find I from it, and we say that the $-j$ shows us that I is 90 degrees behind E. In equation 4, Q is also referred to E in phase. There is no deeper or more obscure explanation of the difference in sign of reactive power than this simple one. All of the more complicated answers stem from it. We can say, if we like, that Q comes out positive when we calculate it in a series circuit of resistance and inductive reactance. It does, but only because here also I automatically becomes the reference point. Similarly, Q comes out negative in a parallel circuit because E is the reference.

It is important to note what happens when equation 1 is obtained from equation 3 merely by the simple act of clearing fractions. To do this, one multiplies both sides of equation 3 by jX, perhaps forgetting that when anything is multiplied by a factor with j in it, the act constitutes a 90-degree phase rotation counterclockwise. The mere clearing of fractions in equation 3 rotates it 90 degrees to bring it into phase equality as well as numerical equality with equation 1 and thus confirms what we have just been saying about these

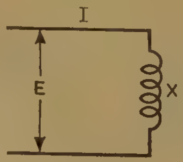


Figure 1

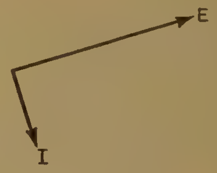


Figure 2

two equations, namely, that their reference points are I and E, respectively, and 9 degrees apart.

Before leaving this matter, I should like to deal briefly with equation 12 in the committee report, where it is stated that for equivalence, the parallel circuit must have an admittance Y given by

$$Y=G+jB$$

For the sake of consistency, I believe this expression should be

$$Y=G-jB$$

for if we recognize the following fundamental definitions of admittance, conductance, and susceptance

$$Y=\frac{1}{Z}$$

$$G=\frac{1}{R}$$

$$B=\frac{1}{X}$$

and if we maintain consistently throughout that X is positive when inductive and negative when capacitive, then for a parallel circuit consisting of resistance and inductance we have vectorially

$$I=I_R+I_X$$

$$\frac{E}{Z}=\frac{E}{R}+\frac{E}{JX}$$

$$\frac{1}{Z}=\frac{1}{R}+\frac{1}{JX}$$

$$Y=G+\frac{B}{j}$$

$$Y=G-jB$$

In other words, if one starts with $Z=R+jX$ for a series circuit, he will find that $Y=G-iB$ for an equivalent parallel circuit. If one wishes, just for the mental exercise, to start with $Y=G+jB$ for a parallel circuit, there is no reason why he should not do so, but if he carries his calculations through consistently to an equivalent series circuit, he will find a perfectly true but unfamiliar and irrational $Z=R-jX$.

I hope I may have contributed something to a better understanding of this matter. Although my own work is not particularly concerned with reactive power, I believe there should be no question about the desirability of the proposed change to regard such power as positive when absorbed by an inductive circuit.

RUSSELL H. LINDSAY (M '42)

(Radio development department, Bell Telephone Laboratories, Inc., New York, N. Y.)

To the Editor:

In the article, "The Sign of Reactive Power," published in the November 1946 issue of *Electrical Engineering* it is recommended that the sign of reactive power be considered positive when the current lags the voltage instead of negative as now defined in the American Standard. I wish to register approval for the suggested change. However, if a change in sign is being proposed, I would like to suggest a change in the name "reactive power." I have always been of the opinion that it was inaccurate and illogical to refer to reactive volt-amperes (vars) as reactive power. In the "American Standard Definitions of Electrical Terms" 05.05.530 power is defined as "the time rate of transferring or transforming energy." According to this definition the average power consumed in a purely reactive circuit is zero, and consequently the reactive component of current often is referred to as "wattless." It is surely inconsistent to call any quantity power which cannot be measured in watts. The word, volt-amperes, can be used both for reactive volt-amperes, Q, or total volt-amperes, S. The total volt-amperes sometimes are referred to as "apparent power." This term is not objectionable in that the word, "apparent," conveys the idea that the power is not real. However, the terms "vector power" and "reactive power" both give the impression that these quantities represent real power.

In the interest of accuracy and consistency I believe that these names should be changed as I have suggested. I believe that in the teaching of electrical engineering the terms as used in this article are very confusing to the student.

GEORGE A. IRLAND (M '35)

(Chairman, department of electrical engineering, Bucknell University, Lewisburg, Pa.)

To the Editor:

It long has been a custom to distinguish between two quantities having opposite characteristics by attaching plus (+) and minus (−) signs to the numbers indicating the magnitudes of the quantities in order that the principles of algebra can be applied. There always arises the question as to which of the two quantities should be considered positive and which should be considered negative. Until a convention finally is established and is understood by all who are interested, there is confusion as to the meaning of the + and − signs. The alternative is to use descriptive words, the meanings of which are self-explanatory. These word signs are clumsy substitutes for + and − signs when developing algebraic relations. On the other hand, if algebraic relations are not called for, self-explanatory words are much superior to + and − signs. This is axiomatic.

The following are examples using the commonly accepted way of attaching + and − signs to the quantities when it is necessary to differentiate between them in any given set of equations:

1. Right +; left −
2. Up +; down −
3. Increase +; decrease −
4. Gain +; loss −
5. *Clockwise +; counterclockwise −
6. Potential rise +; potential fall −
7. Leading phase angle +; lagging phase angle −
8. **Capacitive var +; inductive var −

The following brief comments are offered on the "practical advantages" of adopting the committee report.

1. *What is the "positive direction?"* The committee cannot mean that reversing the convention in regard to the signs of reactive power will reverse the direction of rotation of a kilovar-hour meter. The laws of nature are not so easily changed.

2. *Why add the phrase "both considered as positive quantities?"* A customer is interested in the accuracy of the meters with which his power is measured but not in the direction of their deflection or rotation. Neither is he interested in the conventions used by engineers in their computations to distinguish between rise and fall, lead and lag, or capacitive and inductive.

3. *If it is necessary to distinguish between rise and fall in potential,* it seems rational to attach a plus sign to the rise and a minus sign to the fall, as is commonly done when distinguishing between a rise and fall in other quantities. What is then more appropriate than to say that "positive reactive power flow produces a voltage rise in the direction of the flow," as in the comment in the committee report.

4. *The general principle is* that the reactive power input to any transmission system equals the reactive power in the system itself plus the reactive power output regardless of which convention is used in the computation.

5. *It is impossible to understand* why a convention in regard to plus and minus signs should interfere with constructing a reactive meter which deflects to the right to indicate inductive reactive power.

To sum up, all necessary algebraic computations can be made equally well using either convention in regard to the sign of inductive reactive power, just the same as all circuit computations are no more difficult when $Z-r-jwl$ than when $Z-r+jwL$. First editions of books by Steinmetz used the convention $F-r-jwL$, with vectors rotating in the clockwise direction rather than in the counterclockwise direction. But with either convention inductive reactive power has the same physical meaning, if indeed it has any physical meaning at all.

But no matter which convention is used in circuit computations, reactive meters can be marked to indicate "capacitive reactive power" and "inductive reactive power" and can be made to deflect or rotate in either direction. This, it seems to the writer, is the practical aspect of the problem, not the convention in regard to the sign of inductive reactive power.

Since computations are made just as easily with one convention as with the other and since the indications of reactive meters need not depend on the convention, the choice of convention should be determined by which appears the more rational.

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*The positive direction of rotation for potential and current vectors is counterclockwise.

**Present American Standard.

It always has seemed to the writer that the standard of reference, if possible, should be taken as the cause rather than as the effect produced by the cause. In our case it happens that in nearly all distribution systems the cause (potential) is substantially constant. This is an added reason for choosing potential as the reference standard. Also in the development of the science the words condenser, capacitor, capacitance, capacitive suggest leading currents rather than lagging voltages, and the words inductor, inductance, inductive suggest lagging currents. If this be so, what is more rational than to make capacitive reactive power synonomous with leading reactive power and to follow the standard convention which represents leading reactive current by a vector which is 90 degrees ahead of the voltage?

W. V. LYON (F '33)

(Professor of electrical machinery, Massachusetts Institute of Technology, Cambridge, Mass.

Amortisseur Action of the Squirrel Cage

To the Editor:

The suggestion of accounting for the synchronous rotary field of the single phase squirrel-cage motor as outlined in the article "The Amortisseur Action of the Squirrel Cage," appearing in the June 1946 issue of *Electrical Engineering*, has raised the question of its utility. It seems that it is not generally understood how this suggestion is applied in practice. It also has been indicated that an outline of its application would be of more value than the outline of the theory.

Although this method is not given in textbooks, it has been applied to repulsion start induction motors for many years. It appears to provide a simpler solution than either the rotary field or cross flux theories, particularly in connection with the lower speeds.

In view of the situation, it seems that the original article should be supplemented by showing its application in a detailed analysis of a specific motor. Such an analysis is submitted herewith.

The single-phase squirrel-cage motor at standstill is simply a stationary transformer having a high reluctance magnetic circuit, large magnetic leakage, and a short-circuited secondary winding. At synchronism, it is the equivalent of the same transformer with open-circuited secondary winding. Thus the various load conditions can be represented electrically by variation of resistance in the transformer secondary.

The primary flux divides: one part, the rotor flux, threads the rotor windings developing energy, while the other part, the leakage flux, bypasses the rotor through the leakage path, developing no energy.

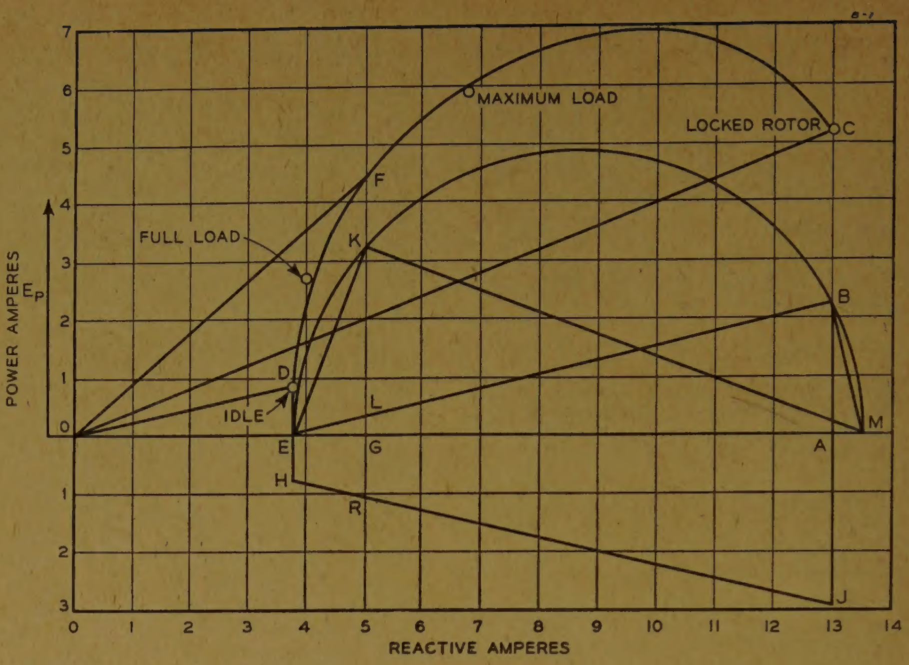
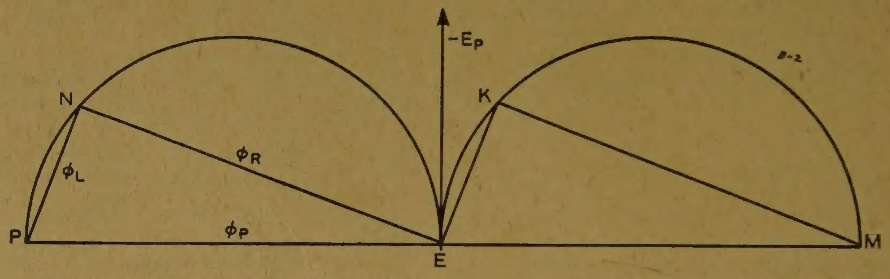


Figure 1 (above)

Figure 2 (below)



At standstill, the amortisseur counter magnetomotive force that opposes flux change in the rotor is in direct space opposition to the primary magnetomotive force, and the bulk of the primary flux bypasses the rotor through the leakage path. However, at synchronism the amortisseur counter magnetomotive force in the rotor shifts into space quadrature with the primary magnetomotive force where it does not oppose the primary magnetomotive force but simply sustains the flux in the quadrature position, and the leakage flux becomes negligible.

Owing to this amortisseur effect of the squirrel cage in opposing flux changes, the rotor flux does not drop to zero, as the leakage flux does, when the primary magnetomotive force becomes zero. As any decrease in rotor flux is opposed strongly by this amortisseur countermagnetomotive force, the rotor flux at standstill must be reversed forcibly against the strong opposition of the rotor amortisseur countermagnetomotive force. This develops strong mechanical forces in the form of a series of double-frequency impulses acting between the primary winding and rotor. These mechanical forces are proportional to the product of the flux forced through the secondary windings and the opposing magnetomotive force developed by the induced rotor currents. Though the forces are large, they act in exact space opposition, and at standstill no torque is produced. However, if the rotor moves between primary magnetomotive force impulses, the rotor amortisseur countermagnetomotive force is carried along with the rotor to a new position, so that, when a succeeding impulse occurs, it is no longer in exact space opposition to the primary, and a torque develops as soon as rotation is started.

As the rotor amortisseur countermagnetomotive force shifts in space from the position of direct opposition to the primary magnetomotive force at standstill to the quadrature position at synchronism, $(1-S)$ 90 degrees is the space angle between the primary and rotor magnetomotive forces at the speed represented by $(1-S)$, where S equals slip in percent, and the total force exerted between primary and rotor multiplied by sin $(1-S)$ 90 degrees is the torque.

The following example of a 1/2-horsepower 220-volt 60-cycle 1,750-rpm repulsion start induction motor will serve to illustrate the application of this method of approach to the problem of the single-phase squirrel-cage motor. The following readings are recorded at a constant voltage of 60 cycles, 220 volts:

1. Amperes, zero speed open rotor, 2.0.
2. Watts, zero speed open rotor, 40.
3. Amperes, synchronous speed short-circuited rotor, 3.9.

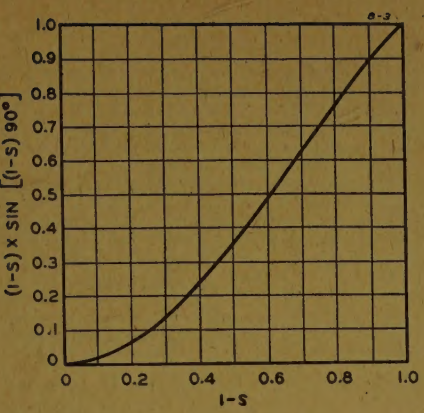


Figure 3

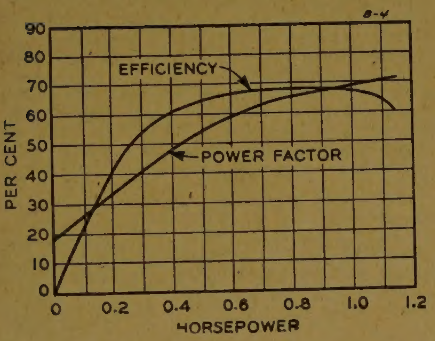


Figure 4

4. Watts, synchronous speed short-circuited rotor, 170.
5. Amperes, locked short-circuited rotor, 14.
6. Watts, locked short-circuited rotor, 1,145.
7. Primary resistance, 3.05 ohms.

Items 1 and 2 are taken at standstill with short-circuiting brushes removed, rotor open circuit.

Items 3 and 4 are taken with motor running idle, rotor short-circuited operating as squirrel cage.

Items 5 and 6 are taken at standstill with rotor short-circuited as in 3 and 4.

Item 7 is measured directly.

These data are plotted with power amperes along the vertical axis and reactive amperes along the horizontal. In Figure 1, point D is located by items 3 and 4 and point C by items 5 and 6. The primary locked rotor I^2R loss is calculated from items 5 and 7. The primary I^2R item plus item 2 is the locked rotor loss outside the rotor. Deducting the sum of these two items CB from the total CA leaves BA, the locked rotor I^2R. A semicircle is drawn, passing through point B and E having its center on the line OM and the arc EKB is the locus of the rotor current as the rotor speed varies from zero at B to synchronism at E.

The primary losses DE and BC are projected below the base line OM with $EH=DE$ and $AJ=CB$, then the points H and J are connected by the line HJ. The locus of the primary current DFC is developed by transferring the primary power amperes above the rotor current locus EKB, so that $RG=KF$ for all positions of the vertical line FR. This operation simply adds the primary and rotor power amperes. At any position of the vertical line FR along the distance EA, it measures the relation of the various quantities as follows: $FK=RG=$primary loss, $LG=$ rotor loss, $KL=$rotor output, $OF=$primary current, $FG/OF=$power factor, and $KL/KR=$efficiency.

As the transformation between mechanical and electric energy takes place in the rotor, the rotor relations may be considered in more detail. In Figure 2, the constant primary voltage E_P develops a constant primary flux ϕ_P in time quadrature. This primary flux divides: one part, the rotor flux ϕ_R, threads the rotor developing energy, and the other part, ϕ_L the leakage flux, bypasses the rotor, developing no energy. As these two fluxes, ϕ_L and ϕ_R, are in time quadrature and their resultant is the constant primary flux ϕ_P, the semicircle PNE is the locus of their vectorial sum. The semicircle EKM, from Figure 1, represents the rotor relations with respect to the primary voltage E_P and the primary flux ϕ_P. The rotor energy current KE requires a flux in time quadrature which is ϕ_R. With change of rotor speed the points K and N move along the semicircles PNE and EKM in exactly similar positions, as ϕ_R is always in quadrature with KE. Since the flux and rotor current diagrams are exactly similar for any position of point K, the flux relations also are shown by the rotor current diagram. Referring again to Figure 1, with EM representing the primary flux, KM is the rotor flux and KE the leakage flux as well as the rotor current.

From geometry, it is known that, as the point K moves along the arc EKB, the product $EK \times KM$ varies directly as KG. As the mechanical force exerted between the primary and rotor varies directly as $EK \times KM$ (rotor current×rotor flux), it therefore, also must vary directly as RG, and since the torque equals this force multiplied by sin $(1-S)$ 90 degrees, torque equals $KG \times$ sin $(1-S)$ 90 degrees.

Likewise, as the segment EKB measures the rotor output, KL, the rotor output, divided by the speed $(1-S)$ also equals torque.

Equating these two torque expressions:

$$\frac{KL}{1-S} = KG \times \sin(1-S)90 \text{ degrees}$$

or

$$\frac{KL}{KG} = (1-S) \times \sin(1-S)90 \text{ degrees} \qquad (1)$$

By measuring the ratio KL/KG directly from Figure 1 and substituting it in equation 1 the numerical value of $(1-S)$ at point K is determined.

To evaluate equation 1 a graph, Figure 3, developed by the use of a table of sines shows the value of $(1-S)$ from zero to 100 per cent in terms of $(1-S) \times \sin(1-S)$ 90 degrees. From this graph, the value of $(1-S)$ for any ratio of KL/KG is determined, and, since $(1-S) \times$ synchronous speed equals the running speed, the speed corresponding to any position of point K can be determined.

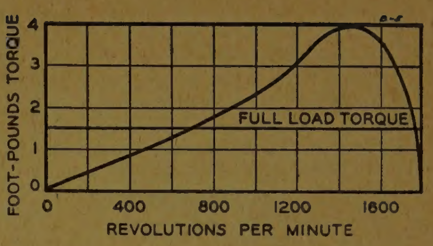


Figure 5

To determine the torque when the speed is known, KL in amperes (Figure 1) multiplied by 220, the voltage, gives the rotor output in watts, which then is transformed into terms of speed and torque by the equation $TS \times 0.142=$watts, where torque is measured in foot-pounds and speed in *rpm*. As the speed and watts are known, the torque is determined readily from this equation.

Figure 4 shows the power factor and efficiency as determined by this method. The four readings taken in routine tests are indicated in Figure 1 and are reasonably consistent.

Figure 5 shows the speed torque relation which is also consistent.

For the sake of simplicity, certain minor items are neglected. As is known, the primary flux decreases slightly under load conditions. Also the double-frequency cross-magnetizing current in the synchronous rotor that equals one half of item 3 is omitted. However, as its I^2R loss is included in item 4, there is no material error here.

At zero speed the amortisseur countermagnetomotive force in the rotor is in exact space opposition to the primary magnetomotive force involving excessive primary currents but no torque. At synchronism the rotor amortisseur countermagnetomotive force shifts to the quadrature position, where it is not in opposition to the primary magnetomotive force but simply sustains the flux in the quadrature position.

At synchronism the primary alternating magnetomotive force is rectified completely in the rotor by its synchronous rotation, subjecting the synchronous rotor to a full-wave double-frequency rectified magnetomotive force.

The synchronous rotary field of the single-phase squirrel-cage motor is due to the mechanical rotation of the amortisseur sustained rotor flux which is revived to full strength each half cycle.

At zero speed the leakage flux exceeds the rotor flux, and this flux leakage limits the motor output. In this particular case, the zero speed leakage flux is approximately 400 per cent of the rotor flux.

The maximum force exerted between primary and rotor occurs when the rotor flux equals the leakage flux.

Edward Bretch (M '19)

(Century Electric Company, St. Louis, Mo.)

NEW BOOKS ● ● ●

"Ideas Have Legs." Doctor Vannevar Bush has said, "Many . . . scientists and engineers . . . are searching their minds as never before in a sincere effort to determine what their duties are and how best to perform them" (*EE, Nov '46, p 508*). "Ideas Have Legs" gives the "what" and "how" of modern man's responsibilities. It furnishes the inspiration for constructive ideas—"ideas that can change men, ideas that can change nations." As engineers we are fully aware that we cannot build securely without standards. Because of the engineer's high standard of integrity and technique, his bridges do not fall. It is the neglect of similar fundamentals in human relationships that has created today's national and world problems. This book sets up the standards and says: "We need not wait for the next generation." It urges men to start now with "an idea big enough to outmatch all other ideas, to mobilize the minds, the hearts and the wills of millions to unity and action." The sales of "Ideas Have Legs" have passed 200,000 in the English-speaking world. Editions are coming out in ten countries. Three of the larger American cities have reported it as one of their best sellers. The author, Peter Howard, tells of his experiences on the winning team for the world's bobsled championship in 1939. The event was supposed to create good will and friendship. Feeling ran high between the national teams, and he found international sports to be an irritant. He also tried politics, as a leading English political columnist reaching 3,000,000 daily through his newspaper. He found statesmen were filled with the disease of materialism, the two chief symptoms were "ingrown eyeballs and itching palms." A part of the book covers Howard's own life and his incessant groping for a great idea to which he could devote his energies. He did find something more exhilarating than football, or bobsledding, or matching wits with politicians, or swaying the readers of his column. Peter Howard finally saw his own part in the war of ideas, and he gives his analysis of how ideas are used in the battle for control of the minds and passions of men. Too many people, he states, forget that God did not design the world to run on the spirit of "Gimme." The signs of "Gimme," he says, are division, broken homes, lockouts, strikes, unemployment, race riots, and wars. Howard goes beyond criticism to cure, stating, "A new world will come through a change of heart in men and nations. It cannot happen any other way. It is the most momentous choice in human history. For one thing is certain. We do stand on the threshold of a new age. A new age of some kind is about to be ushered in, with all the sweat and blood and agony of new creation. It can be God's idea of a new age. If not, it will be a new age of another kind. And we, the ordinary men of our nation, we alone, the citizens of destiny, decide." Frederick Muller, Ltd., London, England, 1945, 190 pages, 5 by $7^1/_2$ inches, 7/6. (Review contributed by M. F. Skinker (F '34).)

"Reference Data for Radio Engineers." This book, first published in August 1943, was received with such enthusiasm that an enlarged and improved second edition recently has been published. In general, the arrangement of the first edition has not been changed. Chapters on transformers and acoustics have been added. Information on vacuum tubes, wave guides, resonators, radio propagation, antennas, and filter design has been greatly augmented. Not only has the book been brought up to date, but it has been enlarged. A useful table of conversion factors and a comprehensive table of unit names, definitions, and interrelations are included in the general information. Also included are expanded data on radio emission and tolerances for various services. The number of circuit formulas has been increased to include T–π and Y–delta transformations, amplitude modulation, transients, selective-circuit formulas, and design formulas for various types of attenuators. The newest method of determining optimum short-wave frequencies required for propagation over specific distances is given. As in the first edition, chapter 1 with generalin formation and chapter 2 with engineering and material data are high in reference value, because these data cannot be found quickly in the average engineer's library, yet often are needed badly. Federal Telephone and Radio Corporation, 67 Broad Street, New York, N. Y., 1946, 336 pages, $5^1/_2$ by $8^1/_2$ inches, $2.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

INTRODUCTION TO ELECTRONICS. By R. G. Hudson. The Macmillan Company, New York, N. Y., 1946. 97 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $3. This book explains the science of electronics and its modern applications in terms that will be understandable and useful to those with only an elementary knowledge of mathematics and physics. It gives a scientifically exact knowledge of the modern theory of the constitution of matter, and the nature of an electric current in a gas, a liquid, a solid, and in a vacuum. It describes and illustrates all of the major uses of electronic tubes and photoelectric tubes, the construction of electronic devices, and their working principles.

INSIDE THE VACUUM TUBE. By J. F. Rider. John F. Rider, publisher, New York 16, N. Y., 1945. 407 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $4.50. The object of this book is to present a solid, understandable concept of the theory and operation of the basic types of tubes. After a simple explanation of the essential electron theory comes a discussion of electrostatic fields. Succeeding chapters discuss the structure and characteristics of the various types of tubes—diodes, triodes, tetrodes, and pentodes—presenting a physical picture of what is happening in the tube. Load lines, power amplifiers, cathode-ray tubes, photoelectric cells, gas-filled tubes, and so forth, also are covered. Mathematical calculations have been kept to a minimum.

ENGINEER AT LAW. Two volumes. By C. B. McCullough and J. R. McCullough. Forewords by J. T. Brand and J. M. Devers. Iowa State College Press, issued in 1946 by The Collegiate Press, Ames, Iowa, under co-operative agreement with the Oregon State Highway Department. $9^1/_4$ by 6 inches, cloth, volume 1, 447 pages; volume 2, 442 pages; $3 each volume. The object of this work is to provide the engineer with a source of information which will help him to avoid legal pitfalls and to deal more efficiently with problems which arise if legal difficulties do occur. Volume I covers court procedures, systems of jurisprudence, and equity considerations. It discusses the important topics of contracts and contractural relationships, engineering specifications, real property laws, and torts incident to engineering operations. Volume II considers the engineer in trial work as technical witness or consultant, and deals with employment relations, patents, negotiable instruments, and numerous special laws of interest to the engineer.

ELECTRICAL TRANSMISSION IN STEADY STATE. By P. J. Selgin. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1946. 427 pages, illustrated, $8^3/_4$ by $5^1/_4$ inches, cloth, $5. The object of this text is to provide students who have had some introduction to the practical aspects of the field with a treatment of the underlying theoretical principles based upon a solid mathematical framework. A variety of problems is used to demonstrate the close basic association in the method of attack. Among the topics presented are the handling of networks as the functional unit of transmission systems and the application of Maxwell's equations to circuit and line analysis.

ELECTRIC MOTOR REPAIR. By R. Rosenberg. Murray Hill Books, New York, N. Y., and Toronto, Ontario, Canada, 1946. Text, 308 pages; illustrations, 243 pages; 9 by 6 inches, paper, loose leaf, binder, $5. The construction and operation of the various types of electric motors, both alternating and direct current, are described in considerable detail. With this groundwork, specific procedures for troubleshooting and repair are given. Over 900 illustrative drawings are included, showing in detail what is treated in the text. The book is so arranged that the text and illustrations are separate so that several pages of text may be consulted while keeping one illustration in view, and vice versa. There is a detailed index.

CAPACITORS. By M. Brotherton. D. Van Nostrand Company, New York, N. Y., 1946. 107 pages, illustrated, $9^1/_4$ by 6 inches, cloth, $3. Capacitors are considered with reference to the basic factors which control their characteristics and which are conducive to success or failure in electronic circuits. Specifically the book discusses for the average circuit designer how a capacitor behaves under direct voltage and under alternating voltage; describes the construction and operation of mica, ceramic, air, impregnated paper, and electrolytic capacitors; and considers the selection of proper capacitors. A separate chapter briefly notes some synthetic dielectrics of the future.

PAMPHLETS ● ● ●

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

List of Inspected Appliances Relating to Accident Hazard, Automotive Equipment, Burglary Protection. Underwriters' Laboratories, Inc., 207 East Chicago Street, Chicago 11, Ill.; 161 Sixth Avenue, New York 13, N. Y.; 500 Sansone Street, San Francisco, Calif.; 79 pages.

Analysis of the 1946 Code Revisions of National Electrical Code, Publication 46-119. National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y., 144 pages, $4^1/_2$ by $6^3/_4$ inches, single copies 50 cents; 30 cents each for ten or more copies.